Division of Agricultural Sciences
UNIVERSITY OF CALIFORNIA

CITRUS GROWING

IN CALIFORNIA

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THIS MANUAL is one of a series published by the University of California and sold for a charge which is based upon returning only a portion of the production cost. By this means it is possible to make available publications which, due to relatively high production costs or to limited audiences, would otherwise be beyond the scope of the College publishing program.

This publication provides growers, or potential growers, with basic information necessary for successful citrus growing. Emphasis is placed on selection of suitable rootstock and scion varieties. Data on orchard location and layout, and on irrigation-system selection, are provided. Details of irrigation, fertilization, and pest control are discussed. Finally, essentials of the business side of citriculture are outlined.

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INTRODUCTION

Citrus growing in California began with the establishment of the first mission at San Diego in 1769. As the mission system grew the Franciscan fathers brought citrus into climatically favored areas. The first orange grove of recorded acreage (six) was set out at the San Gabriel Mission near Los Angeles about 1804. In 1841 William Wolfskill planted the first commercially profitable acreage at Los Angeles; the orchard eventually utilized 70 acres. More planting was stimulated by the Gold Rush, but it was not until the 1880's that an industry developed as a result of the successful fruiting of the Washington navel orange at Riverside and completion of the first transcontinental rail service.

From 1880 until the mid-1950's most of the California citrus crop was produced in southern California. During that period central California, northern California, and the desert areas provided a minor portion of the total volume grown. Following the end of World War II, industry, population growth, and tristeza (quick decline) forced thousands of citrus acres out of production in the southern part of the state. From 1945 to 1956, Valencia orange acreage decreased by 52,949 acres and navels by 21,832 acres.

To fill the need for greater orange production, a large planting expansion has taken place since 1955 in the San Joaquin Valley and to a lesser extent in the desert areas and outlying districts of southern California. Citrus fruit now grows commercially in California from San Diego County in the south to Glenn County in the north, a distance of approximately 600 miles. The areas of commercial production are shown by varieties on pages 2 through 6.

MAJOR PRODUCTION AREAS

Coastal. This area is comprised of the southern California counties of San Diego, Orange, Ventura, Santa Barbara, San Luis Obispo, and the southwestern part of Los Angeles County. The climate is equable, with considerable fog, cool summers, mild winters, and relatively high atmospheric humidity due to the proximity of the Pacific Ocean. Some districts are subject to occasional strong desiccating winds in winter and spring. Rainfall averages from 11 to 20 inches.

Intermediate. This zone includes parts of Riverside, San Bernardino and Los Angeles counties. The climate is characterized by hot, dry summers, bright days and cool nights with occasional strong drying winds. Rainfall varies from 10 to 15 inches from year to year and locality to locality.

Central California. This region lies in the southern and central San Joaquin Valley and includes the foothill and adjacent terrace lands of Kern, Tulare, Fresno and Madera Counties. Warm, dry summers and cold, foggy winters prevail.

Navel orange growing areas.

Valencia orange growing areas.

Lemon growing areas.

Grapefruit growing areas.

Tangerine, tangelo, and tangor growing areas.

Spring and fall weather is usually mild but with occasional hot spells. Rainfall gradually increases northward amounting from 4 to 6 inches in the south end of the valley to 12 inches in the north. Strong spring and fall winds in the southern end and west side of the valley occasionally blow leaves and fruit off the trees.

Northern California. This section includes parts of Butte and Glenn Counties in the Sacramento Valley. Strong south winds contribute to the disease, "citrus blast." Rainfall is from 17 to 20 inches a year. As in the San Joaquin Valley, warm summers and cold, foggy winters prevail.

Desert. This area lies in the low elevation Colorado desert and includes Coachella, Palo Verde and Imperial Valleys. Rainfall ranges from 0 to 4 inches. Occasional strong, drying winds blow in fall, winter, and spring months. Extremes of summer heat and dryness characterize the desert areas of California.

Fruit in the desert area ripens earliest. Fruit in central and northern California matures next despite being 300 to 600 miles further north than areas of southern California. Fruit in the intermediate zone ripens later, and in the coastal area last.

Because of the climatic differences between the producing areas, California with only two major orange varieties markets oranges throughout the entire year. However, the loss of late maturing acreage to population growth in the milder climatic areas in recent years may cause serious marketing difficulties. Shipments of Marsh grapefruit extend over a 10-month period. Two varieties of lemons, Eureka and Lisbon, provide fresh fruit the year around. The Eureka is largely confined to the mild coastal districts. Lisbon grows well in all frost-protected areas. Fruit classified under mandarin and mandarin hybrids are marketed from November through April.

COMMERICAL VARIETIES—DESCRIPTION, UTILIZATION, PRODUCTIVITY

Oranges, lemons, and grapefruit are the most important kinds of citrus fruit grown in California. Mandarins and mandarin hybrids are grown in limited areas. Occasional plantings of limes, and a few acres of citron in the warmest locations, comprise the balance of the commercial citrus acreage. Their relative importance and distribution are shown in the table on the following page.

The California citrus industry is based upon five important commercial varieties: Washington navel and Valencia oranges, Eureka and Lisbon lemons, and Marsh (Marsh seedless) grapefruit. Each of these varieties has been superior in over-all characteristics to a large number of minor varieties tried commercially since the beginning of the citrus industry in California.

To attain commercial acceptance a citrus variety must have good market and good eating qualities. Market quality is associated with appearance, firmness, freedom from blemishes, uniformity, suitable thickness and texture of rind, with the ability to withstand considerable handling and storage. Eating quality is influenced by: flesh texture, juiciness, total solids content (principally sugars), total citric acid, ratio of solids to acids, aromatic constitutents, and vitamins and mineral content. Achieving maximum market and eating quality is the goal which the successful grower seeks.

Total acreage (by county) of commercial citrus fruits, 1967*

County	Navel‡	Valencia‡	Lemon	Grapefruit	Mandarin, Mandarin hybrid, Tangelo, Tangor	Lime	Total
Butte	360	—	—	—	—	—	360
Glenn	2,090	230	—	—	—	—	2,320
Fresno	11,780	3,210	440	—	140	—	15,570
Kern	8,840	3,640	650	—	520	—	13,650
Madera	2,110	410	—	—	—	—	2,520
Tulare	51,630	24,300	2,670	130	1,450	—	80,180
Imperial	—	840	330	450	710	—	2,330
Los Angeles	960	1,510	2,450	—	—	—	4,920
Orange	340	19,810	900	150	—	—	21,200
Riverside	14,250	12,010	4,070	10,740	6,350	130	47,550
San Bernardino	10,520	6,160	3,760	1,700	380	—	22,520
San Diego	1,020	9,200	2,200	200	780	320	13,720
San Lius Obispo	—	—	400	—	—	—	400
Santa Barbara	—	—	4,580	—	—	—	4,580
Ventura	2,030	21,210	24,440	910	—	—	48,590
Other†	280	160	60	120	270	60	950
State total	106,210	102,690	46,950	14,400	10,600	510	281,360§

* Source: California Crop and Livestock Reporting Service

† Total acreage of counties with less than 100 acres each.

‡ Approximately one-third of the total acreage is non-bearing.

§ Total does not include 610 acres miscellaneous orange varieties.

The Washington navel orange

At full maturity this variety is unexcelled as a dessert fruit. Consumers prefer its attractive deep orange color, rich flavor, seedlessness, crisp flesh, large size and the ease with which it may be peeled and segmented. Products manufactured from navel oranges helps salvage fruit unsuitable for the fresh market, but returns from this seldom pay much more than harvesting costs.

Ripening varies from year to year, depending on temperature. Harvesting usually begins in early November, and much of the crop grown in central and northern California is picked and shipped before Christmas. Harvesting of the southern California crop usually gets underway by mid-December.

Environmental differences markedly affect Washington navel fruit quality. Cool humid summers contribute to larger fruit size, poor color development and delayed maturity. Desert-grown navel

oranges yield poorly, are lower in acid, and are less flavorful. Best fruit quality depends on the right amount of total heat available during the growing season, and favorable minimum and maximum temperatures. Regions of optimum growth and production are central California and the intermediate areas of southern California.

Navel orange trees are somewhat weaker and less productive than other orange varieties.

In the recent large citrus expansion in central California, three times as many Washington navel orange trees have been planted as all other citrus varieties. Because of better yields and vigor, the Frost nucellar Washington is widely used as a replant and for general orchard plantings. Despite rigorous competition from Florida's expanding winter orange production, demand for California grown navel oranges has been fairly steady.

Over the past 50 years more than a dozen bud sports (variants) of the Washington navel orange have been selected and propagated commercially. None proved superior to the standard type in fruit quality or productivity. Indeed, the most important feature in propagating this variety is the necessity of maintaining true-to-type fruit. Nevertheless, some variant types listed below have been commercially useful:

The Atwood navel. Although not as flavorful as the Washington, the Atwood navel has certain characteristics that reccommend its use. In early locations it may produce a fruit that attains legal maturity up to 10 days ahead of the standard Washington navel. Most outstanding is its late holding characteristic. The smooth, highly colored rind and the fruit remain firm and in good marketable condition longer than any other navel orange type.

The Thomson Improved (T.I.) navel. The variant most widely used until the Atwood strain appeared was the Thomson Improved. Its favorable characteristics are its earliness and smooth rind texture. Excessive rag, inferior flavor, and somewhat flattened shape, plus short tree and storage life of the fruit and lower productivity, restricts its use.

The **Tule Gold** and **Skagg's Bonanza,** newest of the early season Washington navel orange variants, are being watched with considerable interest. They are so recently introduced that it is too early to tell whether or not they will attain commercial importance.

Gillette, Carter and Newhall navels have found favor because of good fruit size and bearing and quality factors in parts of southern California. They do not appear promising for general use in central California.

Because of the prevalence of certain virus diseases and poor fruit characteristics, the **Robertson** navel, once widely planted and heralded as a heavy producer of early fruit, proved generally unsatisfactory. This bud sport suffers in many respects in comparison with the standard Washington navel. Most commercial groves of the Robertson have been removed.

The Valencia orange

Still the leading orange variety in California, the Valencia (unlike the Washington navel) produces well over a wide range of climatic conditions. For long season fresh fruit use, however, the most favored areas for Valencia production are the interior districts of the coastal areas. The tree is vigorous and fairly cold resistant. This high-quality fruit has few seeds, firm tough rind, and superior juice characteristics, thus making it useful for fresh shipment as well as for juice products.

Valencias are usually harvested from February to May in the desert, from mid-March to July in central California and

from April to November in southern California.

Problems with this variety are its susceptibility to drying of the pulp vesicles (granulation) when held on the tree after maturity. After the fruit ripens it tends to regreen. Both of these disadvantages result from physiological changes that occur in most citrus fruits when they are held on the tree after maturity. However, "tree storage" is generally preferable to commercial cold storage.

Because of better yields and vigor certain Valencia strain selections are preferred. The Olinda, Campbell and Frost nucellars are favored.

> Considerable variability exists in citrus varieties. Propagation of off-types results from the difficulty of distinguishing them, and from careless bud selection. Consequently, it is important to buy trees propagated from sources known to produce good crops of quality fruit in the general area where the orchard is to be planted.

The Eureka Lemon

The Eureka is most commonly planted in coastal areas where fruit is picked over a 9-month period. The tree is spreading, open, and moderately vigorous. It is more subject to frost injury than other commercial lemon varieties. It tends to bear most of its fruit on the tips of fruiting wood, so it is subject to sunburn, wind scarring and cold damage. Since the old line Eureka lemon is weak and short lived, nucellar or young line selections are preferred. Allen, Cook and Frost nucellar are selections in current use.

The Lisbon lemon

This variety is suited to all lemon districts. It is a large, vigorous, dense spreading tree. Its fruits are borne on the inside of the tree where they are protected from sun, wind and cold. Most of the fruit matures in the fall and winter, especially in the interior areas. Lisbon trees are generally thornier than Eureka, and because of their hardiness are not as severely injured by cold weather, nor are they as seriously affected by extreme heat or strong winds. The Lisbon produces more fruit than the Eureka, partly because of its larger size and bearing area. Hence the Lisbon variety is planted further apart than the Eureka. The most popular strains (clones) are the Prior, Frost nucellar, Rosenberger, Monroe and Limonera 8A.

The Marsh grapefruit

Commercial grapefruit production in California is based on the Marsh variety. Its popularity is due to its few seeds, good fruit shape and high quality. Desert-produced grapefruit is harvested in the winter and early spring. In intermediate areas, fruit maturity is slower to develop and top quality is seldom achieved. Fruit from this area may bring good returns as no other grapefruit may be available. Cold, damp weather predisposes the fruit to rind blemishes.

Greater interest has developed in variants of the Marsh—red and pink fleshed selections. Color development of these selections in the desert and warm interior valleys is good.

Mandarins and mandarin hybrids, tangelos, and a tangor

In recent years interest has developed in the mandarin group which is presently marketed as tangerines or tangerine-type fruits. Production and fruit quality of these varieties are particularly sensitive to environmental conditions. The following are some of the more important char-

acteristics and major problems of the leading varieties:

Clementine (Algerian) tangerine This variety has medium-sized fruit which ripens in November and December in the desert, and from December through February in coastal and interior regions. It is the major tangerine variety available for the holiday trade. The red-orange, medium sized, sweet fruit peels easily and is favored by consumers.

The chief problems are low yields and alternate bearing. The fruit is also subject to granulation, particularly in desert areas. Granulation is more serious with young vigorous trees and with trees growing on rough lemon rootstock. Pollination by another variety is essential. Dancy tangerine appears to be the best pollen source. Interplanting with Valencia orange or Kinnow mandarin may aid pollination. Bees disseminate the pollen.

Dancy tangerine. This small to medium sized, easily peeled, deep orange-red colored fruit ripens in the coastal-interior areas in February and March and in the desert in December through February. Because of lateness of maturity, small fruit size and susceptibility to frost, the Dancy should not be planted in the colder districts. Alternate bearing is also a problem.

Kara mandarin. This medium to large orange-colored fruit ripens in coastal-interior areas in March through May, and in the desert in February and March. The pulp has a deep rich yellow-orange color and a unique flavor. The fruit peels easily and is seedy but will not tolerate cold and does not appear promising in the desert. Alternate bearing may be a problem.

Kinnow mandarin. The medium yellow-orange colored fruit ripens in coastal-interior areas in February through May and in the desert in December through February. It has an excellent, rich, spicy, pleasant flavor but peels with difficulty. The tree produces heavily in alternate years.

Satsuma mandarin. This medium to small, easily peeled, seedless, orange-colored, mild sweet fruit ripens in the coastal-interior areas in November through January. It is not suitable for the desert. Most of the acreage is in Tulare County where this variety is utilized largely in the colder localities. Trees and fruit tolerate more cold than any other citrus grown commercially in California. Fruit matures before the other mandarins and when marketed ahead of the Clementine usually commands a good price when the quality is satisfactory. With young trees, poor fruit quality is often the rule; until tree vigor slows the fruit is frequently rough and unattractive. Production is comparable to navel oranges; as with the Washington navel, immature fruit is subject to June drop in years when the weather is hot during the crop-setting period.

Wilking mandarin. This medium to small, orange-colored, rich flavored fruit ripens in the coastal-interior areas from February through May and in the desert in January through March. Because of its small size and tendency toward granulation it is not favored for the desert. As with most mandarins and mandarin hybrids, alternate bearing is a problem.

Minneola tangelo. The attractive large scarlet-orange colored, somewhat tart, rich flavored, difficult to peel fruit ripens in February through April in the coastal-interior areas, and in December and January in the desert. Although the tree tolerates considerable cold, the thin-peeled fruit is fairly sensitive to frost. Like the Clementine cross pollination with Dancy tangerine, Valencia orange or Kinnow mandarin helps set better crops. Even with pollination in some years, the Minneola tangelo is a shy producer.

Orlando tangelo. Its medium to small orange-colored, mild flavored, hard to peel fruit ripens in January through March in the coastal-interior areas and in November and December in the desert. In some sections, particularly the San Joaquin Valley, preharvest drop of fruit may appreciably reduce the crop. Like the Minneola, it needs a pollinator.

Temple tangor. The large red-orange colored tart to sweet flavored fruit ripens in January and February in the desert and in March and April in the coastal-interior areas. It is best suited for the desert. It is unlikely that it will be used elsewhere, particularly in the San Joaquin Valley where the rind tends to become very rough and the fruit coarse and dry.

Limes. Limes are quite frost sensitive and some are consequently grown in the most frost-free areas. Two general categories are represented commercially in California—the Mexican (West Indian or Key) limes and the Tahiti group chiefly grown as the Bearss lime. Since the Mexican lime is most sensitive to cold, and is difficult to harvest because of its thorniness and small fruit, it is seldom grown. The Bearss lime is more cold resistant, less thorny, seedless, and a heavier producer of larger fruit. The Bearss lime tree grows larger and is more densely foliated. The most serious defects of this variety are the tendencies towards stylar or blossom-end rot, and production of the crop during late fall and winter.

> NEW EXPERIMENTAL VARIETIES
>
> Many new varieties are in the process of evaluation, and some appear to be near commercial acceptance. To avoid costly errors each new variety must undergo extensive field trial. Trees should grow in the general location of prospective commercial use long enough to determine adequate performance, standards of production, fruit quality, and marketability.

Nucellar embryony and nucellar varieties

Seeds of most citrus species produce two kinds of seedlings—those which result from pollination, and the nucellar seedlings derived entirely from tissue of the fruit-bearing or "mother" parent. The portion of a seed which grows into a seedling is called the embryo. Sexually-produced embryos result from the union of a male or pollen cell and a female or egg cell. This type of embryo derives heritable characteristics from each parent and is therefore unlike either, although it may resemble them.

In citrus seeds, the development of a sexual embryo stimulates cells in the surrounding tissue to form additional embryos. This is why one citrus seed may produce two or more seedlings. These extra embryos do not result from sexual union but grow entirely from tissues of the seed-bearing parent. Like buds, they reproduce the characteristics of the parent from which they were derived. Seedlings of this kind are called nucellar because they develop from the nucellus tissue. In many instances the sexually-produced embryo fails to develop and only the nucellar embryos grow.

Nucellar seedlings grow more vigorously and are more upright and thorny than old-line trees. Young line trees usually come into bearing slowly, but when they reach maturity the growth behavior becomes characteristic of the variety from which they originated except that it is more vigorous and usually more productive. Trees which are propagated from bearing nucellar seedlings become fruitful about as soon as comparably aged old-line parent-variety trees.

Nucellar varieties have been developed from all commercial varieties except the Clementine mandarin and Temple tangor. Because of their vigor and fruitfulness they have been widely planted. Budded on vigorous rootstocks and amply supplied with water and nutrients, fruit quality may suffer in comparison with less vigorous old-line varieties. This tendency appears more often with the grapefruit and navel orange varieties. As the trees age and growth slows, however, fruit quality of the young lines will be found to be comparable to that of the old lines.

ROOTSTOCKS

Most commercially-grown citrus trees are budded to seedling rootstocks of a variety grown for that purpose. Rootstocks are chosen for scion compatibility and on the basis of adaptability to soil and water conditions, ultimate tree size, cold hardiness, favorable effect on production, fruit size and quality, and nematode and disease resistance.

Troyer citrange. This rootstock has the characteristics of vigorous growth, cold resistance when mature, some tolerance to nematodes and to brown rot gummosis and tristeza (quick decline). It has been used as a replant rootstock and is adaptable to most soils. Troyer citrange became the most widely planted rootstock for oranges following the discovery that sour orange was subject to tristeza. Like trifoliate orange and other citranges, Troyer is stunted by the exocortis virus. It is therefore essential that scion varieties used on Troyer be free of this disease.

The fruit on young, vigorously-growing orange trees may be large, rough and coarse. As with other invigorating rootstocks, young trees and fruit may be quite sensitive to cold—as the trees age they withstand cold better than most other rootstocks. Troyer appears to be a good rootstock for Lisbon lemons but cannot be used for Eureka lemons. It is also satisfactory for grapefruit and mandarins.

Trifoliate orange. This is the hardiest of all commercial citrus rootstocks. Both tree and fruit grown on trifoliate are more resistant to cold than on other commonly-used rootstocks. Fruit quality is generally enhanced when produced on this root, largely because of its ability to add to the solids and acid in the juice. Trifoliate orange is adapted to the climate prevailing in the San Joaquin and Sacramento Valleys. It does not produce as large a tree where total heat units in the growing period are less.

Alkaline, calcareous and salty soil and water limit the usefulness of trifoliate. The rootstock is particularly sensitive to excess salinity and alkalinity and to micronutrient deficiencies—particularly zinc and iron. When trifoliate grows in soils having a high clay content, it does not produce as large a tree as with medium-textured soils.

Trifoliate is intolerant to the exocortis virus and stunts badly when budded to sources carrying this disease. On the other hand, trifoliate is most resistant to citrus nematodes and to brown rot gummosis. It makes a good replant when climate, soil and water conditions favor its use. Trifoliate is tolerant of tristeza.

Under usual conditions of growth, trifoliate roots produce somewhat smaller than standard size orange and grapefruit trees. Occasionally no dwarfing effect has been observed. Trifoliate is not generally used as a rootstock for Lisbon lemons and because of incompatibility is not used for Eureka lemons. Scion growth is reduced and tends to defoliate in some winters. Experimental plantings with Lisbon lemon on trifoliate, however, indicate possible commercial use for this combi-

nation. Mandarin trees are dwarfed on trifoliate root.

Sour orange. Until tristeza killed thousands of orange trees growing on this rootstock, sour orange was accepted as one of the best. Bud union overgrowth eliminates it as a desirable rootstock for lemons. Other citrus varieties do better on other commercially available rootstocks, so little propagation of citrus trees on sour orange stocks is done.

Cleopatra mandarin. This rootstock has the characteristics of longevity, satisfactory fruit quality, and good productivity in later years. Cleopatra mandarin was chosen as a possible replacement for sour orange. This stock shows considerable tolerance to alkali and salts. Although resistant to *Phytophora citrophthora,* it proved susceptible to *P. parasitica* infection. Root rot involving the latter fungus limits the usefulness of Cleopatra mandarin to soils not previously planted to citrus. Other drawbacks are its smaller than average sized fruit and its slowness in coming into full production. It is resistant to tristeza.

Bud union overgrowth of lemons on this rootstock precludes the use of this combination.

Sweet orange. This stock is regarded as a satisfactory rootstock for all commercial citrus varieties. Its chief disadvantages are its susceptibility to brown rot gummosis, a tendency to produce somewhat smaller than average sized fruit and poor growth as a replant. It is best adapted to medium-textured soils of good drainage. Because of its susceptibility to gummosis it is not recommended for soils with considerable clay content.

In a statewide experiment involving 18 orchards over a 20-year period, Dr. F. F. Halma of the University of California, found there was no difference in either Valencia or Washington navel orange clones grown on their own root as compared with budded sweet-orange seedlings, with one exception: on an adobe clay soil all the navel orange cuttings developed foot-rot, but seedling rootstocks did not become diseased. It appears that certain strains of sweet orange tolerate brown rot gummosis more than others.

Frost tolerance and fruit quality of trees budded to sweet orange are average. The stock tolerates tristeza as well as do other commercial rootstocks.

Rough lemon. Since rough-lemon rootstock produces coarse-textured fruit low in solids and acid, its use cannot be recommended for an industry based on production of high-quality dessert fruit. Although it grows rapidly and yields large crops of good-sized fruit in lighter soils, granulation with some scion varieties (particularly in the desert areas) is worse with this rootstock. Both trees and fruit on this stock are usually more susceptible to cold injury than are trees on other commonly used rootstocks.

Brown rot gummosis develops on rough-lemon rootstocks as readily as on sweet orange. Lemons and oranges often decline in 10 to 15 years when grown on this stock, particularly on clay soils. Rough lemon is tolerant to tristeza.

Grapefruit. Use of grapefruit as a rootstock has declined owing to generally variable growth and production, but there are some good yielding orchards on this stock. Fruit maturity develops slowest on this rootstock; for example, in many seasons Washington navels in central California cannot be picked until after the first week in January. This stock is susceptible to brown rot gummosis and is adversely affected by tristeza. Lemon collapse appears more often on grapefruit than on other rootstocks.

Alemow (*C. macrophylla*). This is the newest of the commercially-tested rootstocks. It is not recommended for oranges, grapefruit or mandarins because

of its susceptibility to tristeza, but shows promise for lemons if the seedlings are not infected with tristeza. Fruit size, quality and productivity have been excellent with lemons on macrophylla root. Considerable resistance to brown rot and good salt, alkali and boron tolerance have been noted, and it seems adapted to a wide range of soils. Citrus macrophylla picks up one-half to one-third as much boron as other rootstocks. It also has the power of absorbing more manganese and iron. At present the most serious limiting factor in its use as a lemon stock is its susceptibility to cold. It has less cold tolerance than rough lemon.

EXPERIMENTAL ROOTSTOCKS

The University of California and the United States Department of Agriculture are actively engaged in evaluating a large number of seedling rootstocks for nematode, disease, cold and salt resistance. The effects of the stock on scion yield, fruit quality and size are also being determined. As these studies indicate rootstocks of commercial promise, they will be made available to the industry.

CHOOSING THE ORCHARD SITE

Factors determining the best location

Relative freedom from frosts is a prime consideration for citrus production. Success in commercial citriculture depends largely on economic production of high quality fruit—but in areas where frost damage is frequent this cannot be attained. Past severe freezes give evidence that a hazard exists in areas that may appear in mild years as suitable for citrus. Lemons, particularly, should be planted in the most frost-free locations. The frost hazard depends on local topography, the path of the prevailing winds or minor air currents, and the efficiency with which frost protection can be afforded. Locate your citrus orchard where local experience or close observations over a number of years show it to be suitable. If you plan to grow an orchard in a new district, you had better plant a few acres at a time in order to evaluate the frost hazard without risking a great deal.

An adequate supply of good quality moderate-cost water is essential to your success in growing citrus. Many growers who depend upon well water have had to deepen wells and install new pumping equipment because of receding water tables. Some orchards have been seriously injured by irrigation water containing large amounts of salts. Boron should not be present in amounts of more than one-half of a part per million. A permanent, adequate source of water free from injurious substances is of fundamental importance. The amount needed varies from 18 acre inches per acre per year near the coast to 9 acre feet per acre in the desert valleys. Water costs should be commensurate with economical production. Careful investigation of water conditions before buying or planting an orchard helps you avoid costly remedies and sometimes impossible situations.

Wind damage may occur from high-velocity gusts, hot desiccating desert winds, or chill prevailing ocean breezes. Do not plant citrus in the path of such winds unless you provide effective wind breaks. Wind can stunt growth, defoliate trees, and scar or blow fruit off.

Heaters and wind machine for frost protection.

Citrus tolerates a wide range of soil types. Trees grow best in uniformly deep, fertile, medium-textured soils free of lens and structural change. With good management, rather difficult-to-handle soils can be used. As with water, salts and toxic elements must not be present in injurious quantities. Sandy soil requires frequent irrigation and fertilization. Clay soil may produce vigorous and productive young orchards, but the trees are frequently short-lived. Since the majority of citrus tree roots—even on deep, well drained soils—grow in the first 2 feet of soil, shallow soils may be successfully utilized. You must be a very good manager, however, to obtain satisfactory growth and production on shallow soils and soils with impeded internal drainage.

Preparing the land

After you determine your site to be satisfactory you will want to prepare the land for planting. No particular treatment is necessary for good virgin soils other than clearing brush, rock or other debris. If

Blue gum windbreak.

the land has been farmed to crops other than citrus, subsoiling to break up compaction layers or growing a deep-rooted green manure crop and plowing it under before setting out young trees helps improve the chances of getting the new orchard off to a good start. With hard-pan soils, deep chiseling (preferably 48 inches or more) helps insure adequate internal drainage. Clay soils with unconsolidated layers gain no permanent benefit from ripping.

Rolling land may be contoured or bench terraced. If much soil has to be moved, the top soil should be stock-piled, the high places undercut and covered with the better top soil. If you use sprinklers and no pockets remain to trap run-off water, and soil erosion does not appear to be a problem, you may be able to set the grove out on the square and disregard the slope. Where the subsoil is considerably poorer than the top soil, you should expect trees planted in scraped areas to be stunted and unprofitable.

The primary objective in grading land for furrow irrigation is to provide a slope that permits even water distribution with-

out eroding the soil. A sandy soil irrigates well with about one-tenth of a foot fall per 100 feet of run. Medium-textured soils require two-tenths and some clay soils need up to six-tenths of a foot per 100 feet to provide good water distribution. Provision for 'tail' water control by using a return-flow system or some arrangement to remove surplus water at ends of furrows can be made when the grade is established.

Before you plant recently-leveled ground, irrigate it thoroughly—any faults in the grade can then be observed and corrected.

On soil previously planted to citrus, a pre-planting treatment with a suitable nematocide will usually boost growth of the young trees.

It is important that the grower control perennial weeds prior to setting out the young trees. It is costly and unsatisfactory to fight established weed pests in newly-planted orchards—"an ounce of prevention is worth a pound of cure" is very applicable here.

SELECTING AN IRRIGATION SYSTEM

Before laying out and planting an orchard, you may enhance fruit production and eliminate costly adjustments by selecting and installing the irrigation system most suitable to your needs.

Furrow system

Most orchards are furrow irrigated. With the furrow system, three to five furrows are made for each row of trees and the water led into the furrows from a hydrant (stand) at the head of each row. The length of furrow depends to a large extent upon the porosity of the soil. With soils having low infiltration rates furrows up to 400 feet in length are used; on sandy soil 250 feet may be too long. Water is usually run through to the end

Pipeline system for furrow irrigation.

Furrow irrigation with tillage.

of the furrow and the valves in the hydrant adjusted to maintain the flow to the end without run-off. This takes considerable skill. To simplify application, a return-flow system may be installed to pick up tail water and deliver it back into the irrigation line.

Satisfactory penetration of water into the root zone requires 2 to 72 hours or more depending on the soil characteristics. You can determine the extent of water penetration by using a sharpened piece of 3 to 4 foot $3/8$-inch steel rod to probe the soil when it is wet, or by using tensiometers (soil-moisture measuring instruments). To minimize differences in penetration between the upper and lower ends of the irrigation run, water should reach the end of the furrows in at least one-fourth the time required for the desired penetration.

On fairly level soils with uniform fall, three wide-bottom furrows per row are generally used. The furrow ridges in the middle support grove traffic and reduce compaction. With variable soils it is sometimes advisable to cross-furrow in areas subject to slower water infiltration.

Contour planting and furrowing on rolling land helps prevent erosion and provides more even water distribution.

Furrow irrigation under nontillage system. Note two broad ridges between three furrows to support orchard equipment.

Basin method of irrigation on mature trees in sandy soils.

Cross-checking the ends of the irrigation run also aids in controlling run-off.

Basin method

In the sandy soils of desert areas where water requirements are high, the basin system is widely used. Under this system land is leveled to nearly or completely zero grade, with levees forming the boundaries of large basins, usually one tree row wide and from 5 to 10 tree spaces long. Large heads of water are used to rapidly fill such basins to the desired depth. Initial costs of leveling and levee formation are higher, but irrigation labor requirements are low under this system.

Another system used in other areas requires considerable land preparation and labor in constructing levees and in water handling. Water is usually run to the lowest basin and worked back until the first or highest basin is filled. This basin method has been largely replaced by sprinkler irrigation.

Basin method of irrigation on young trees. Note unirrigated area between rows.

Sprinkler irrigation

Sprinkler use has greatly increased—especially on hilly land—where low-volume sprinklers are coupled on plastic drag-hose lines. With sprinklers operating in a well-engineered system discharging water according to the trees' needs, it is possible to maintain and in some cases improve tree health and productivity and to utilize the non-tillage method of culture. When soil texture varies and hardpan or clay layers impede water absorption, or when the terrain is rolling and uneven, sprinklers are quite useful provided they are adjusted to discharge amounts needed.

With coarse-textured soils, sprinklers discharging several gallons per minute can be used, but with fine-textured soils less than a half a gallon per minute may be all the soil will absorb. The sprinklers are usually set to throw water in the square between four trees, very little water being thrown high enough to wet much foliage. Three sprinklers are attached on each drag lateral and are moved after a 12-, 24-, or 36-hour interval. There are usually enough sprinkler lines to cover the grove with a solid irrigation in from 5 to 10 days.

Some growers seeking to reduce labor costs install permanent over-the-tree sprinkler systems. The first consideration when irrigation wets the foliage is water quality. More than 100 ppm chlorides may "burn" the leaves. Calcium carbonate in the water leaves a white deposit that may interfere with leaf function. Iron deposits stain leaves and fruit. Another matter of some importance is the loss of effective spray residues by washing. An added problem lies in the fixed pattern of wetting that comes with a permanent installation. This may be unimportant for trees growing on sandy, well-drained soil, but is serious with poorly-drained, clay or hardpan soil. A possibility that light sprinkling when hot weather strikes during the fruit setting period will cool the trees sufficiently to prevent or reduce "June" drop has prompted some growers to install permanent overhead sprinklers. However, at present there appears to be no proof that such irrigation procedure is economically justified.

Filter installation for low-pressure dragline sprinkler system.

Low head, dragline sprinkler irrigation system with nontillage.

LAYING OUT THE ORCHARD

Determining the most productive spacing

Planting distances depend on the scion variety, soil type, rootstock and climatic influences; each of these factors has an important effect upon the size of the mature tree. The usual permanent spacing for oranges and grapefruit is in rows 20 to 26 feet apart, with trees spaced the same distance or a couple of feet closer in the row. Lemon trees are planted in rows from 22 to 26 feet apart and frequently 18 to 22 feet apart in the row. When grown on the same soil and on the same or comparable rootstocks, Eureka lemon trees need less space than Lisbons. Washington navel orange trees need less space than Valencias or grapefruit.

If you want to attain full production quickly, plant more trees per acre. Double setting is the usual way of doing this. However, hedge-row trees may eventually fall off in production due to shading important fruit-bearing surfaces. Trees set at intervals that crowd mature growth must be pruned; the tighter the setting, the more severe the crowding. Pruning to alleviate crowding removes a certain amount of fruiting wood. When and how much to prune to maximize production in crowded groves is a difficult problem to solve. You may avoid this by planting on a "standard" spacing or by treating the alternate trees as fillers, never permitting them to crowd the permanent trees. Continuous high production results from growing the maximum bearing surface per acre. You either grow large trees far enough apart to develop bearing surfaces all the way to the ground, or you plant a larger number of smaller-growing trees and keep them smaller to maintain their bearing surfaces.

Direction of rows

In order to facilitate irrigation, you may be forced to plant your trees in the direction of the land slopes. If you have a choice and you wish to double-set your grove, your trees will be better illuminated by having them in north-south rows. Try to avoid blocking a cold-air drift.

Surveying and marking for planting

For the best utilization of your land and to prevent boundary disputes, establish your boundaries before you survey and mark for planting. If your acreage is rectangular you may use your boundaries as your base line. (Base lines are straight lines running in two directions from which all measurements are made.) One base line parallels the row and the other the line formed by the first tree in each row. Base lines at right angles to each other are common and convenient but not essential. A good tractor driver can locate tree holes by pulling a chisel from base lines at the desired interval. The point where the chisel marks intersect is the tree hole site. Most growers, however, use planting lines to mark the rows and planting distances. Wires or chains are marked at points to indicate the spacing and are stretched from the base lines. A hand full of powdered gypsum dropped at the mark indicates the point at which the tree hole will be dug; or the tree hole location may be indicated by a short stake.

Digging tree holes

Most growers prefer to dig the tree hole with an auger mounted on the back of a tractor. The holes need only to be deep enough to accommodate the roots or ball of the tree, and wide enough to permit easy filling—however, if the holes are unnecessarily deep excessive settling will occur after planting the trees.

CHOOSING AND PLANTING THE TREES

How to recognize a well-grown tree

Success in citrus production depends largely on the vigor and inherent capacity of the tree to produce large crops for many years. No combination of good soil and water, favorable climate and skillful management can overcome the handicap of poor trees. For this reason buy the best trees obtainable—even a slight increase in production or length of life repays the small added cost of superior trees.

Good citrus nursery trees have large, deep green, thrifty leaves, and bright, clean bark. The bud union should be smooth and preferably 8 to 10 inches above the soil level to avoid infection by the organisms that cause gummosis. Avoid rootstocks held longer than normal in the nursery before budding, as they are likely to be stunted or inherently less vigorous. These older rootstocks may be identified by the marked difference in diameter between stock and scion. The scion should be nearly as thick as the stock. (Trifoliate orange and Troyer citrange rootstocks tend to be larger than the scion.)

It is desirable to select trees in the nursery before digging. This helps you avoid receiving weak trees or trees which have been picked over or left in the nursery too long. If you can't do this, get trees that have grown in one or two flushes. If growth is checked at intervals, there will be joints and characteristic markings on the bark at points where growth

stopped. Such trees are not necessarily undesirable. Growth may be checked by weather changes, temporary lack of moisture, or other external causes having only a transitory effect on the trees. On the other hand, the cause may be a weak or incompatible rootstock or a diseased bud or root—in which case reject the trees. If you note poor growth or yellow leaves, examine the roots. Dead areas on the main roots or a lack of feeder roots are causes for rejection.

Age and size of tree to plant

Citrus nursery trees are usually dug 1 or 2 years after budding. Most growers prefer 1-year buds because it takes a good tree to reach marketable size in one growing season after budding. One-year-old bud shoots ordinarily have leaves on their trunk—older trees do not. (Trees produced in hot interior areas grow more rapidly, and may shed leaves from the trunk before they are dug. Mite infestation or drought may also cause leaves to drop.)

Nursery trees may be graded according to the diameter of the trunk 1 inch above the bud union. Well-grown yearling trees measure $\frac{3}{8}$ to $\frac{3}{4}$ inch in diameter, and 2-year-olds measure $\frac{3}{4}$ to $1\frac{1}{4}$ inch.

Productive capacity—budwood and rootstock source

How fruitful the tree becomes and the kind of fruit it produces cannot be judged by its appearance as a young tree in the nursery. Buds should be taken from trees producing true to type fruit. Budwood mother trees should also be long-lived, high-yielding, and free from disease. Rootstock and scion varieties to be planted must be compatible and suited to the soil and locality where the trees will grow—this is essential to remember.

Because you must take the word of the nurseryman as to bud source and rootstock used, be sure you deal with an experienced, reliable person. Insist on obtaining the registration numbers of budwood source trees. Keep a record of blocks where they are planted.

> The California Department of Agriculture, Bureau of Nursery Service, maintains a budwood registration program to identify source trees. They must pass certain requirements as to freedom from some serious virus diseases, and they must be of good vigor and free from apparent mutations and disorders which might obscure disease symptoms or make the tree undesirable as a budwood source.

Within the various species used as rootstocks are numerous strains differing in their suitability. For this reason, seed for rootstock propagation should come from old trees which have remained free from disease and which are known to produce uniform, vigorous seedlings that make good trees when budded to the variety to be grown. Limited quantities of such seed are available and the more progressive nurserymen own or have access to such trees.

Planting the trees

Most growers prefer to take advantage of the long California growing season by planting in early spring. Trees planted during late February to May usually grow better than trees planted in summer and fall. Early-planted trees are more apt to grow sufficiently to harden enough foliage to better withstand low temperatures. Mid-summer is a poor time to plant because hot weather and drier soil makes it difficult to dig and plant the trees without

considerable shock. Fall planting of balled trees may succeed in mild, frost-protected localities.

Bare root versus balled trees

In California, most citrus trees are dug with a ball of soil held in place by a burlap wrapping. This helps prevent damage to the rootlets and enables the trees to make a quick start. By leaving the main root system intact, drying by exposure to light and air is avoided. Unless you are prepared to take special precautions, you had better plant balled trees.

To preserve as much of the root system as possible, the balls should be about 14 to 18 inches long and 8 inches in diameter. Examine the balled trees you receive and either reject or hold them for a few weeks if the soil appears broken away from the roots by careless handling. By holding the balled trees you may be able to determine whether or not they have been injured sufficiently to cause failure in planting. The soil in the ball should be nearly the same texture as the soil you plant in. Otherwise, it will be difficult to maintain proper moisture conditions. Avoid holding balled trees more than a few weeks; if held, the trees must be shaded and kept moist.

Trees dug bare root present certain advantages—you can preserve more of the root system and you don't have to be concerned about matching the soil in the ball with the soil in your orchard. You can see what the roots look like and reject trees with diseased or crooked ones; and they may be cheaper to plant. You must, however, handle bare root trees more carefully to avoid drying out. You may have to defoliate the top to help prevent this. If the trees must be shipped long distances, they may be enclosed in polyethylene sheets or bags and held for a few weeks in a cool, dark storage. If they are to be planted immediately following digging, you may wash them free of soil and slip them into plastic bags or cover them with damp sawdust or other suitable material until set in the tree hole. They should not be held in water—this often causes root injury.

Planting methods

Use of a planting board helps you set the trees at the proper height and get them in straight rows. The board is usually about 4 feet long, notched in the center and at both ends. (Many growers do not choose to bother with a planting board but trust to a good eye or to luck that the trees are set at the proper height and in line.) Place the center notch over the marking stake and drive pegs into the ground at the notches in the end of the board. Remove the center stake and board to leave the end pegs as guides for digging the tree hole and planting the tree. After the hole is dug, place the planting board over it so that the planting pegs fit the end notches. Then place the tree in the hole, setting the trunk at the center notch of the board. Set the tree in such a way that after settling it will be no lower than it was in the nursery. Be sure and cut the tie around the burlap at the junction of root and stem. Peel the burlap back and stuff it in the planting hole after you have filled and tamped in enough soil to hold the tree upright, but before you finish backfilling.

The uppermost roots should branch near the ground level and the bud union should be well exposed. These precautions are important because trees set too deep are an invitation to trouble from brown rot gummosis. Many trees withstand fungus infection the first few years only to be killed as they come into production. Replacements of such trees are costly.

Immediately following planting, irrigate the trees thoroughly. If you start your planting at the upper end of the row

you can run water down the furrow as you plant, otherwise tank or hose water immediately. Should the trees be set either too high or too low, reset them at the proper height as soon as possible.

Care of newly planted trees

Irrigation. No other cultural operation is as important as proper irrigation. To insure ample moisture, construct either a small basin (about 2 feet across) around the tree sufficient to hold 3 to 4 inches of water or make a berm or ridge on either side of the tree row so that the water you apply thoroughly wets the tree roots with every irrigation. With sprinkler irrigation you may find it most satisfactory to apply water through small fixed-head "splits" the first year or two rather than sprinkle large areas where there are no roots.

Tree protectors. Many growers find it best to apply impervious light-colored paper tree wraps around the trunks as soon as possible after planting. This provides sunburn and rabbit protection and prevents most unwanted suckers from developing. If the wraps are to remain on the trees throughout the winter, a thorough Bordeaux application to the trunk should be made before the rainy season starts, preferably at the time of wrapping. You may want to use paper-backed fiberglass wraps and leave them on a couple of years. Be sure the ties cannot girdle the trees.

Training (suckering, pruning). After citrus trees outgrow their juvenility they attain a hemispherical shape without pruning. Their strong wood and habit of growth usually provides them with sufficient strength to bear normal crops without breakage. In heavy crop years the

Insulated wrap for cold protection (also serves as protection from sun).

Corn stalk tree-wrap for cold protection. Note tight wrap around trunk with branches exposed.

trees may be propped or tied. With young trees, you had best remove any fruit that might cause breakage. Fruiting depresses growth; hence maximum growth is obtained when all the fruit is removed soon after fruit set. For this reason some growers pull all the fruit off 1- or 2-year-old trees.

When you receive your trees from the nursery, they will come as "whips" or "canes" or as cut-back "headed" trees. Should you be tempted to prune them before they come into bearing, with the intention of developing a structurally strong frame work of branches, remember that pruning young citrus trees depresses total growth, delays fruitfulness, and tends to stimulate sucker development at or near the cuts. About all you need to do the first few years is to rub off undesirable suckers as they appear. This controls unwanted growth on the trunk and main limbs. If you miss a shoot and it becomes a vigorous sucker growing in such a manner as to unbalance the tree or become subject to breakage, you may cut it off near the terminal to make it branch.

Frost protection. Before the grove comes into production you may find it hard to justify the expense of frost protection by means of heating and wind machines. One thing to do is to protect the trunk and major scaffold limbs with an insulative covering. Corn stalks, thickly placed so that the trunk sees no light, are as good as most insulative materials. The usual method is to tie well-dried stalks upright against the trunk 3 to 4 inches thick and snug enough to retain the latent heat of the trunk and main branches.

Trees are fed by materials produced in green leaves in the presence of light. Therefore, covering the whole tree starves it and it becomes more sensitive to cold. It is better to risk some leaf injury than to cover the leaves and starve the tree.

See to it that the trees never suffer from drought. Cold kills dry trees more easily than trees well supplied with moisture. On the other hand, some retardation in growth by withholding moisture just before the onset of cold weather hardens the tree to cold. If you can run water in furrows beneath the trees during cold nights, you may get a 2 to 4 degree rise in temperature.

Finally, if the orchard has sandy soil you can "bank" it around the tree up to 24 inches. This method is used widely in Florida but has not been employed or recommended (except in a few instances) in California, principally because of our problem with brown-rot infection in finer-textured soils.

Fertilization. It has often been said that the best fertilizer one can put around a young tree is good garden loam. Certainly the back-fill soil used in planting the tree should be fertile enough to provide ample food for the roots as they emerge from the ball. If you must plant in soil poor in minerals essential to growth, it may be helpful to provide the tree with the necessary nutrients through cautious use of slow-release fertilizers. Placement of highly soluble inorganic concentrate fertilizers or "hot" manures in the planting hole is not advisable. For newly planted trees scatter *not more* than an ounce of chemical nitrogen carrier (ammonium nitrate, calcium nitrate, etc.) in the furrow or basin around the tree—repeat, but not more than three or four times during the season.

Disease and pest control. Prevention is the best cure. Keeping the trees healthy by ample but not excessive irrigation and fertilization, and suppressing competitive weed growth that might harbor insect enemies, helps you detect and control troublesome pests and diseases before you sustain crippling losses. (See discussion on disease and pest control for things to guard against.)

Irrigation. In California good irrigation practice is of paramount importance. Citrus trees are evergreen and require readily available soil moisture at all times. Since rainfall is confined largely to the winter season, irrigation is necessary 6 to 12 months of the year. The amount of irrigation water required varies from 18 acre-inches per year near the coast to 36 or more acre-inches in the interior. As much as 9 feet per acre per year are used in some desert plantings. Climatic conditions determine to a large extent the total amount of water needed, but soil type as well as size and vigor of the trees determine frequency and amount of water required at each irrigation.

Water applied to a citrus grove is used by the trees, evaporates from the soil surface, or transpires through cover crops, or percolates below the root system. Your job is to see that the tree is adequately supplied and percolation losses minimized or utilized to remove excess salts—where this is a problem. Avoid unnecessary irrigation, especially where the drainage is impaired and removal by the tree is slow. Excessive moisture in the soil provides an environment that favors root decay, which in turn causes decline in tree vigor and productivity. On some soils good irrigation is not possible unless you provide artificial drainage. Most difficulties ascribed to over-irrigation are actually caused by poor drainage.

Many soils contain large amounts of lime. To reduce or avoid chlorosis (loss of green coloring matter from the leaves), irrigate as little as possible. Where the soil or water, or both, contain excessive soluble salts, occasional heavy irrigation helps leach the salts out of the root zone. When you must use copious amounts of water, allow soil to dry down to the wilting point before irrigating again.

Do not determine the time interval between irrigations by the calendar or by the soil type, but base it on the rate of use by the trees. This differs according to the season but can be determined by systematic observations of the soil occupied by the roots. One of the best ways to keep a check on moisture needs of citrus trees is to employ soil tensiometers—properly installed and serviced, they provide a good guide as to when to irrigate. Where the soil salinity is not high, gypsum blocks are also useful for the same purpose. Experienced growers may be able to judge moisture needs by noting the appearance of the soil and the trees—but this is, at best, a hit-or-miss affair. Growers seldom examine the soil frequently enough to properly gauge the needs of the plants.

The amount of water applied at each irrigation depends on the capacity of the soil to hold water and the depth to which the soil is occupied by roots needing moisture. Except where leaching is needed, apply only enough water to wet the soil in the zone where the roots are dry. Excess water goes beyond the reach of the roots or aggravates already moist soil conditions; it carries soluble plant nutrients below the root zone.

Alternate middle irrigation. The practice of running water down every other tree middle instead of down every middle at each irrigation helps solve some problems relating either to inadequate or to excessive water application. In applying half the water ordinarily used at each irrigation, it permits irrigating twice as often without over-irrigating.

Advantages of alternate middle irrigation

For shallow soils. Most roots in shallow soils reach the wilting point at about the same time. Sometimes the interval be-

tween irrigations can be adjusted to compensate for weather conditions, provided water is available on call. When water cannot be applied as needed, cutting the interval in half prevents sudden, complete exhaustion of water supply.

Avoiding water shortage. If irrigation intervals are lengthened because of a water shortage, alternate middle irrigation prevents prolonged water deficits toward the end of an irrigation interval. Trees and fruit remain in fair condition despite a moderate but continuous water deficit.

Replants. Alternate middle irrigation permits cutting water into the replants from both sides. Thus, the replants can be irrigated twice as often as when water is applied all at one time.

Avoiding root injury. Roots may be damaged if water is used at the regular interval to overcome water stress.

When roots have been injured, alternate middle irrigation, properly applied, could gradually correct the damage. Hardpan and clay soils are predisposed to trouble resulting from excess moisture. On clay soils, the period between irrigations may be lengthened safely without subjecting the trees to serious wilt.

Lime-induced chlorosis. The danger of lime-induced chlorosis on calcareous or high-lime soils often is reduced by using less water. The soil can be dried out without serious wilting of the tree by irrigating alternate middles or irrigating less frequently.

Salt accumulation. Where a limited amount of salty water is used, it is imperative to get sufficient penetration to avoid salt accumulation. Shallow irrigation results in salt buildup in the soil. It is possible to reduce by half the amount of water needed to adequately wet the root zone. To do this, confine each irrigation to one side of the tree, thus limiting the surface area of wet soil.

Moisture as it relates to tree growth and production. Ideally, maximum tree growth and fruit size are achieved when all roots are supplied with all the moisture they can absorb under conditions favoring absorption and growth. It is practically impossible to provide these conditions throughout the year.

The maximum rate of transpiration depends directly upon how much of the root system is in contact with available moisture. The need for maximum moisture usually occurs only during periods of high temperatures and drying winds. Insufficient moisture can seriously limit the crop when trees are blooming or setting fruit. Trees with healthy root systems, amply supplied with moisture, set and mature the best crops.

In many soils the greater danger is from excessive irrigation during periods when the trees do not need copious moisture. A timely system of alternate middle irrigation, with frequent checks on soil moisture, may place a borderline orchard on the profitable side.

Alternate middles vs. alternate furrows. The use of alternate furrows to wet both sides of the tree at the same time does not produce the same results as alternate middle irrigation. It is nearly impossible to prevent rewetting areas already wet from a previous irrigation. Due to soil differences, there are many spots where water from one furrow penetrates into the adjacent furrow.

Fertilization

Proper fertilization is essential to tree health and productivity. Nutrient deficiency or excess limits yields. Fortunately for most citrus growers, California soils are generally well supplied with most of the essential elements except for nitrogen and some micronutrient elements. "Balanced" or "complete" fertilizers are generally a waste of money and may actually

contribute to poor growth and production. Proper fertilization, then, amounts to determining what elements are needed, and supplying them in sufficient amounts at the proper time by the correct method.

Since the soil may be regarded as a storehouse which contains the elements needed for plant growth, you might be tempted to conclude that a chemical analysis of a representative soil sample would provide the information you need to determine your fertilization program. Soil sampling for this purpose is practically worthless. Physical and chemical composition of California soils varies from location to location and from season to season. It is, therefore, virtually impossible to obtain representative soil samples to determine your fertilizer needs. Furthermore, some elements may be present in forms unavailable to citrus trees, and even though the chemist determines the total amount of minerals in the soil no test has yet been devised which indicates their availability to plants. Fertilizer requirements can best be judged from leaf analysis and by controlled field trials.

Unless experimental application of fertilizers are carefully controlled and accurate growth and production records taken, erroneous conclusions may be reached. It is, therefore, much simpler and less costly to rely on leaf analysis and visual evidence from symptomatic leaf patterns and growth behavior. This pro-

Tentative leaf-analysis guide to deficient and non-deficient bearing mature orange trees

Element	Unit (dry wt.)	Deficient	Ranges*			
			Low	Optimum	High	Excess
N	%	< 2.2	2.2 to 2.3	2.4 to 2.6	2.7 to 2.8	> 2.8
P	%	< 0.09	0.09 to 0.11	0.12 to 0.16	0.17 to 0.29	> 0.30
K†	%	< 0.40	0.40 to 0.69	0.70 to 1.09	1.10 to 2.00	> 2.30
Ca	%	< 1.6?	1.6 to 2.9	3.0 to 5.5	5.6 to 6.9	> 7.0?
Mg	%	< 0.16	0.16 to 0.25	0.26 to 0.6	0.7 to 1.1	> 1.2?
S	%	< 0.14	0.14 to 0.19	0.2 to 3.0	0.4 to 0.5?	> 0.6?
B	ppm	< 21	21 to 30	31 to 100	101 to 260	> 260
Fe	ppm	< 36	36 to 59	60 to 120	130 to 200?	> 250?
Mn	ppm	< 16	16 to 24	25 to 200	300 to 500?	> 1000?
Zn	ppm	< 16	16 to 24	25 to 100	110 to 200	> 300
Cu	ppm	< 3.6	3.6 to 4.9	5 to 16?	17 to 22?	> 22?
Mo	ppm	< 0.06	0.06 to 0.09	0.10 to 0.29?	0.3 to 0.4?	—?
Cl	%	?‡	?	< 0.3	0.4 to 0.6	> 0.7
Na	%	?	?	< 0.16	0.17 to 0.24	> 0.25?
Li	ppm	§	—	< 3	3 to 10	> 10?
As	ppm	§	—	< 1	1 to 5	> 5?

* Based on concentration of elements in 5- to 7-month-old spring-cycle leaves from nonfruiting terminals. Adapted and revised from Jones and Embleton.

† K values relate to number of fruit per tree.

‡ ? indicates information not complete.

§ These elements are not known to be essential for normal growth of citrus.

vides a guide that reflects the complex interaction of soil, water, climate and the trees themselves. Soil analysis is, however, useful to determine the soil reaction, toxic ions, total salts expressed by electrical conductivity ($EC \times 10^3$ millimhos) and exchangeable bases.

Leaf analysis

Research in plant nutrition has determined the amounts of the chemical elements in plants associated with normal growth and production. Standards are now tentatively defined for those elements important in citrus nutrition. Sampling and analyzing citrus leaves provides information that serves as a guide in determining a fertilization program. It also helps evaluate previous practices.

Values in the table (page 30) are for *bearing* navel and Valencia oranges. Tentative evidence suggests that desirable levels for lemons are similar, but grapefruit values may be slightly lower. Leaves from young trees should show higher nitrogen values.

Field deficiencies of calcium, sulfur, molybdenum, and chloride are not known in California.

Sampling suggestions

It is extremely important that a proper sample be collected, for the analysis is no better than the sample. If in doubt, it is best to have the laboratory making the analysis also do the sampling.

To obtain a true picture of the nutrient status of a grove, leaves are taken from healthy trees only. A leaf analysis from weak or diseased trees does not reflect the true condition of an orchard. Diseased trees often show nutrient-deficiency symptoms. These are not generally caused by lack of nutrients in the soil; rather they are caused by diseased roots or lack of roots, trunk and limb disorders, or foliage troubles which prevent the tree from utilizing available nutrients. If nutritional status of trees growing in abnormal or unusual conditions is desired, trees should be sampled separately.

A map showing the sampling route helps evaluate the uniformity of the block and enables duplication of the sampling site year after year. The route should cover a representative portion of each uniform area (a diagonal or circle through the block enables the collection of a meaningful sample.)

Two leaves each from 35 to 50 trees makes an adequate sample. Leaves are taken so as to sample each of the four sides of the tree. This is done by pulling leaves from two sides of the tree on a diagonal course through the sampled block, taking north and east leaves from every other tree, and south and west leaves from the alternate tree.

Oranges and grapefruit are sampled in mid-August to mid-October, taking leaves from non-flushing, non-fruiting terminals of the spring-growth flush. For lemons, hardened leaves of the last fully developed cycle without fruit or new growth are sampled in the same period—mid-August to mid-October.

Normal leaves, shoulder high, are taken at random without regard to size from the terminal portion of the correct growth flush. Where trees have received pesticide treatment, postpone sampling for 2 weeks. Misleading values for zinc, manganese and iron may be obtained if leaves recently sprayed with these elements are sampled: values in the optimum range may result while subsequent growth flushes will be in the deficient range. The sampler and the laboratory doing the analysis must know of recent micronutrient applications to adequately perform the analysis and interpret the results.

Interpreting the analysis

When values for the elements are in the low or deficient range, apply fertilizers

that improve the nutrient level. Excess of some elements, particularly nitrogen, frequently causes interference with proper uptake of other important elements. Consequently, you may attempt to correct this imbalance by withholding elements in excess before you start applying deficient elements. (Your Farm Advisor can help you interpret your analysis and decide on a fertilizer program.) Your initial leaf analysis may include nitrogen, phosphorous, potassium, calcium (as an indication of leaf age), manganese, magnesium and other elements about which you may want information. Your subsequent annual leaf sample may be only for the purpose of determining the nitrogen level. However, it is wise to re-analyze for the above every 5 years in order to keep track of general nutrient levels.

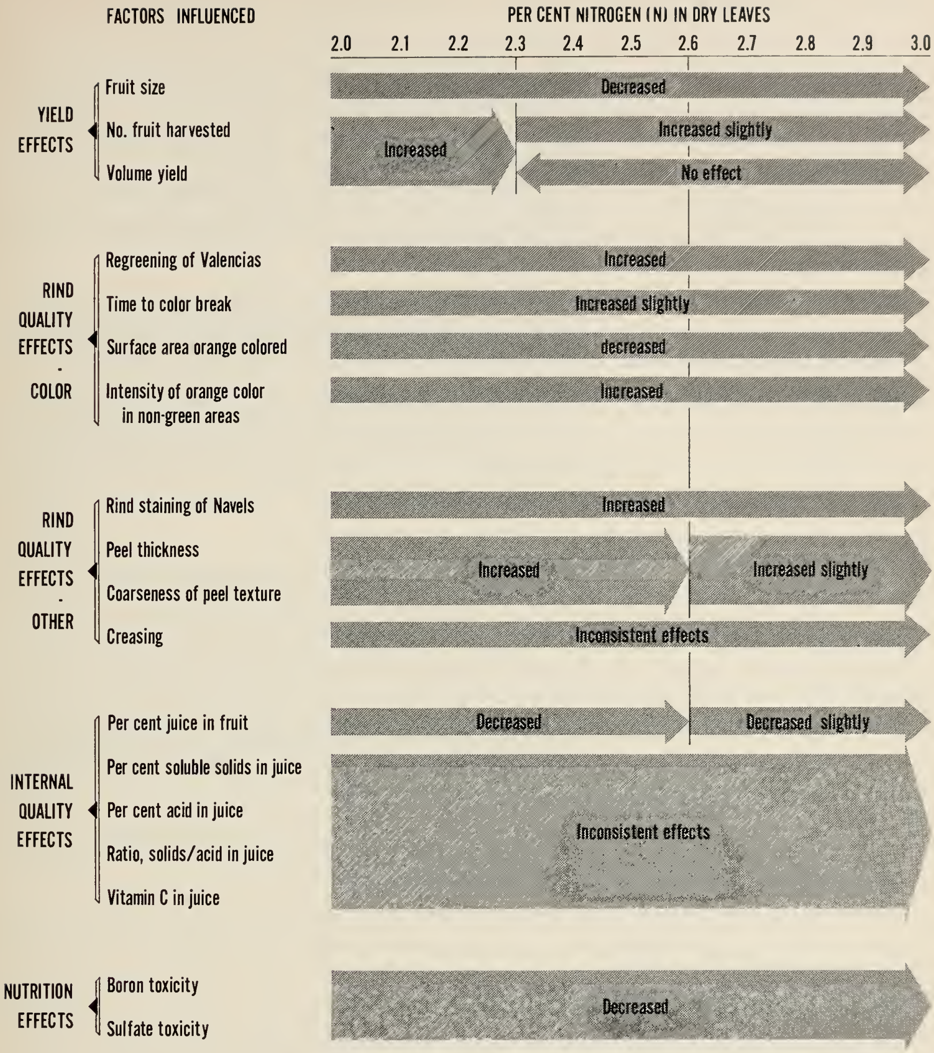
Macronutrients. Large amounts of these elements are used by citrus trees. See page 35 for abnormality symptoms.

Nitrogen. All citrus trees sooner or later require nitrogen fertilization unless the irrigation water carries considerable nitrates. Nitrogen stimulates growth and is essential to fruit setting. Excess nitrogen causes coarser fruit, contributes to regreening of Valencias, sensitizes the tree and fruit to cold, and delays fruit maturity. Contrary to the popular notion that nitrogen makes fruit grow bigger, fruit size cannot be improved by adding nitrogen during the growing season—good irrigation does that. To maintain leaf value of nitrogen in the optimum range, the usual rate of application is from 1 to 1½ pounds of elemental nitrogen per tree per year; sometimes up to 3 pounds may be required to bring leaf values up to the desired range. Rapid uptake of nitrogen from an application of 7½ pounds low biuret urea in 100 gallons of water as a spray helps relieve acute nitrogen hunger, and is useful as a pre-bloom application to supplement soil-applied nitrogen and to help set the crop.

Where boron and sulfate excesses occur, nitrogen applications to give values in the high range may be necessary to partially reduce the effects of these excesses.

Phosphorus. Most citrus soils in California contain ample phosphorus to adequately meet the needs of the trees and whatever cover crops grow between the tree rows. However, there are a few areas (mainly in San Diego County) where phosphate fertilization is sometimes necessary to obtain and maintain thrifty trees with high yields of acceptable quality fruit. Since phosphorus is rapidly fixed in neutral to basic soils, little if any becomes available to citrus trees with the usual applications obtained from mixed fertilizers. If the trees need phosphorus, apply 10 to 25 pounds of treble-super phosphate on the soils around the tree.

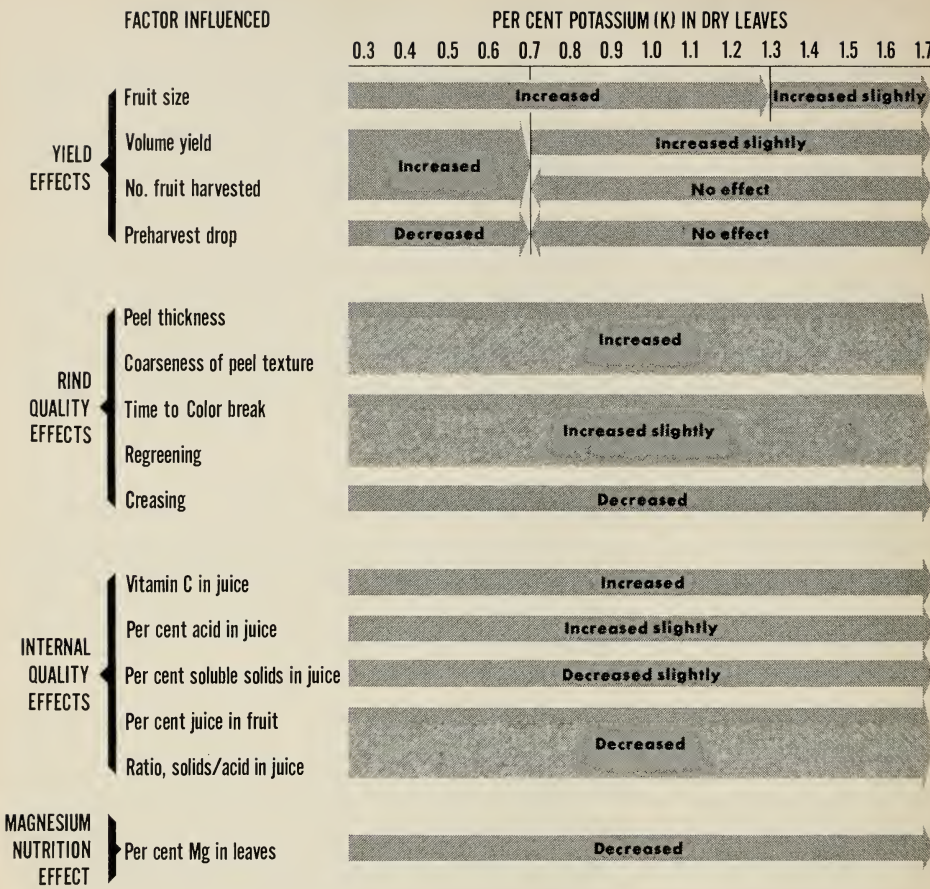
Potassium. As with phosphorus, most California citrus soils are amply supplied with potassium. A few orchards show rather low values and may respond to potassium. Trees deficient in potassium yield reduced crops of small fruit. High potassium levels cause large puffy oranges that mature late. Lemons appear to respond to higher potassium values, and fruit quality improves with ample potassium. Ten to 25 pounds of potassium sulfate per tree applied to the soil is the usual dosage rate where potassium fertilization is indicated. As a means to supply potassium rapidly to trees the application of potassium nitrate spray has been successfully used. Thirty pounds of potassium nitrate per 100 gallons of water, applied when leaves are two-thirds expanded, provides potassium in cases where soil applications of potassium fertilizer are ineffective or slow to react. The influence of leaf potassium levels on various factors is shown on page 34.



Influence of percentage of nitrogen in 5- to 7-months-old bloom-cycle leaves from nonfruiting shoots on yield, rind quality, internal quality, and magnesium nutrition of oranges. (From Embleton, Jones, and Platt, 1957.)

Magnesium. In recent years a number of citrus orchards have exhibited symptoms of magnesium deficiency. Poor growth as well as increased cold susceptibility result from lack of magnesium. The only satisfactory way to relieve magnesium hunger is to spray the trees when the leaves are two-thirds to three-fourths expanded in the spring with 10 pounds of magnesium nitrate per 100 gallons of water. To provide magnesium cheaply you may derive magnesium nitrate by mixing magnesium sulfate with calcium nitrate in the spray tank.

Magnesium sulfate applied to the soil may eventually provide needed magne-



Influence of the percentage of potassium in 5- to 7-months-old bloom-cycle leaves from non-fruiting shoots on yield, rind quality, internal quality, and magnesium nutrition of oranges. (From Embleton, Jones, and Platt, 1957.)

sium, but field tests thus far are not encouraging. Magnesium hunger is aggravated by excessive irrigation and heavy applications of manure or excessive potassium fertilization.

Micronutrients. Small amounts of these elements are needed. See table, page 36, for abnormality symptoms.

Manganese. Deficiency of manganese appears to be increasing in many areas. Lack of this element reduces growth and fruitfulness. Correction is generally rapid when sprays containing manganese are applied.

Zinc. Most citrus trees sooner or later require added zinc. One or two foliage applications are needed per year in some zinc deficient areas. As with manganese deficiency, zinc hunger reduces growth and fruitfulness. Soil applications of zinc are not usually effective.

Copper. Copper deficiency occurs infrequently. Lack of copper reduces production and fruit quality. This trouble is found occasionally in old corral soils and in localized areas. Copper fungical treatments normally provide enough of this

Symptoms of Physiological Abnormalities Due to Faulty Mineral Nutrition

Macronutrient element	Deficiency			Excess		
	Leaves	Fruit	Tree growth	Leaves	Fruit	Tree growth
Nitrogen (N)	Pale yellow to old ivory, small, veins yellow. Sparse.	Reduced crop.	Reduced. May produce abundant bloom. Flower buds may fall without opening.	Deep green, large.	Coarse, tends to regreen. Develops poor color, low solids. Sensitive to rind disorders.	Vigorous, then reduced due to mineral imbalance. Increased cold sensitivity.
Phosphorus (P)	Small, dull.	Reduced crop. Large, puffy, bumpy surface, thick rind, enlarged core cavity.	Reduced.	Lighter green. Tends to defoliate.	Reduced crop. Small fruit.	Poor, twig dieback.
Potassium (K)	Old leaves curled and chlorotic. Drop prematurely.	Small, thin rind. Smooth. Drop prematurely.	Reduced.	Shed prematurely. Marginal brown.	Poor quality. Coarse, large oranges. (Lemons tolerate more K. May require more for best quality.)	Reduced.
Magnesium (Mg)	Yellow mottling along margin, devel oping into a green wedge, to make "Christmas tree" pattern. Eventual complete yellowing and defoliation. Mature leaves full-sized	Reduced crop.	Reduced. Increased cold sensitivity.			

(Continued)

Symptoms of Physiological Abnormalities Due to Faulty Mineral Nutrition

Micronutrient element	Deficiency			Excess		
	Leaves	Fruit	Tree growth	Leaves	Fruit	Tree growth
Boron (B)	Curl and pucker. Corky veins, metallic to brownish yellow. Gum pockets.	Heavy drop of young fruit. Gum pockets.	Reduced "Cabbage head" growth.	Chlorotic mottling. Resinous raised areas, brown to yellow spots. Dead area at tip and margin defoliation. Lemons and limes most sensitive.		Dieback, reduced. Death.
Copper (Cu)	Deep green, over-sized, then darkened.	Splitting and gumming. Dark brown, gum soaked eruptions. May turn black. Gum in center core.	Twigs enlarge at nodes, blister, dieback, gum pockets. "Cabbage head" growth.	Defoliation.	Discoloration. Premature drop.	Bark gumming, stunted. Death.
Iron (Fe)	Yellow, veins remain green until final stage of general chlorosis. Reduced size.	Reduced crop.	Eventually reduced.			
Manganese (Mn)	Normal green along main veins. Balance of leaf pale green to light yellow.	Reduced crop.	Eventually reduced.			
Zinc (Zn)	Mottled yellow between main veins, small narrow. Early fall. Reduced size.	Reduced crop. Some pale yellow off-type.	Eventually reduced.	Defoliation, burn.		Dieback. Death.

element to correct deficiency problems. Where this is not the case copper sprays may be required.

Iron. Alkali and excess salinity contribute to iron deficiency; over-irrigation aggravates it. Iron-deficient trees grow poorly and production suffers. Proper irrigation is often the best treatment. Chelated iron compounds applied to the foliage or soil occasionally may help overcome iron chlorosis. Rootstocks vary considerably in their ability to pick up iron; of the commercial rootstocks, trifoliate is poorest and Alemow the best iron forager.

Boron. Boron deficiency is quite rare in California. On the other hand, boron excess is common to areas where the irrigation water carries more than one half part per million, and in certain localities having residual boron in the soil. Rough lemon and macrophylla rootstocks tolerate higher boron levels than other commercial rootstocks. Lemons and limes are more sensitive than oranges or grapefruit. Boron moves through the soil slowly and there is no known treatment that quickly removes it. The harmful effects of boron excess may be reduced by heavier than normal nitrogen application.

Chemical nitrogen fertilizers

Nitrogen fertilization is critical at one time or another in all citrus orchards, and it is a major cost item in the fertilization program. Commonly used chemical nitrogen sources are the following compounds: ammonium nitrate, calcium nitrate, ammonium sulfate, urea and ammonia.

Nitrate nitrogen moves in the soil readily and is carried by water in which it is dissolved. It is a good form to use, particularly when a rapid effect is required.

Nitrogen in the ammonia form becomes absorbed by soil particles near the soil surface and usually remains absorbed in the surface until it is oxidized to the nitrate form by soil organisms. Some ammonium ions are absorbed by citrus roots directly but most convert to nitrate before becoming available. When ammonia is applied to basic (alkaline) soils, there is some loss to the air from exposed surfaces. Applied to the irrigation water, losses to the atmosphere increase with temperature rise and turbulence of the water. If applied in late winter or early spring when temperatures are low, losses are negligible and may be disregarded. Some losses occur when granular ammoniacal fertilizer lays on the soil surface, so it is best to apply such material just ahead of a good rain or in the furrow bottom where it will be dissolved by irrigation water soon after application.

On certain soils low in calcium and organic matter, chemical nitrogen carriers (calcium nitrate excepted) tend to reduce the rate of water penetration. This lowered infiltration effect can be avoided by reducing tillage, growing winter cover crops, using manure, and distributing all fertilizers evenly over the root zone. In central and northern California, addition of gypsum to irrigation water is often necessary to maintain adequate soil calcium essential to good soil structure.

Young trees may require split applications of nitrate nitrogen. For oranges and grapefruit on most citrus soils, a single application of chemical nitrogen during the winter or early spring is sufficient; split applications may be required for lemons and young trees.

Because there is little difference in the general effectiveness of these fertilizers, you should *buy on the basis of applied cost per pound of actual nitrogen.*

Nutrient sprays provide a quick and sometimes surer way of adding needed elements and controlling nutrient levels. Many growers fertilize (at least in part) by this means. Best results occur when sprays are applied over leaves when they are about two thirds expanded and cer-

Comparisons of common fertilizers

Chemical fertilizer	Nitrogen (per cent)	Pounds of nitrogen per ton*	Pounds per tree to supply approx. 1 pound nitrogen	Pounds per acre to supply 1 pound nitrogen per tree at 90 trees per acre
Ammonium sulfate	21	410	5	450
Ammonium nitrate	33.5	670	3	270
Calcium nitrate (nitrate of lime)	15.5	310	6	540
Anhydrous ammonia (liquid ammonia)	82	1640	1¼	112
Ammo-phos (16–20)	16	320	6	540
Liquid mix (10–10–5)	10	1 pound per gallon	1 gallon	90 gallons
Urea	45–46	910	2⅙	196

Manures	Nitrogen	Phosphate (per cent)	Potash (per cent)	Pounds of nitrogen per ton	Pounds per tree to supply 1 pound nitrogen	Tons per acre to supply approx. 1 lb. nitrogen per tree at 90 trees per acre
Dairy manure (dry)	1	0.5	1.8	20	100	4½
Feed yard steer manure	2	0.6	1.9	40	50	2¼
Poultry manure (No. 1)	2.5	2.5	1.2	50	40	1¾
Poultry manure (No. 2)	1.5	1.3	0.9	30	66	3

* To compare prices, divide this figure into the ton price to determine cost per pound of nitrogen.

tainly before they are fully mature. Very tender growth is sometimes injured by such spray materials. Urea applications to help fruit setting may have to be applied before the spring flush reaches the most favorable stage of growth for maximum effectiveness.

Metal chelates are chemically stable metal organic materials showing promise of correcting certain micronutrient deficiencies. Their use must still be considered experimental. It is advisable to see your Farm Advisor for suggestions for soil or foliage application.

Note: When mite and insect control is weakened by spray desposits, foliar feeding may have to be postponed.

Use of plant-growth regulators

In recent years a large number of growers have applied the isopropyl ester of 2,4-D to prevent preharvest fruit drop, reduce premature leaf drop and (with Valencias in southern California) to increase fruit size. Gibberellic acid, or the potassium salt of gibberellic acid, is used to delay fruit maturity, to reduce navel orange rind staining and to obtain favorable effects on the delay of aging and softening of the rind. When use of these growth regulators are indicated, follow the label instructions carefully. When in doubt, consult your Farm Advisor.

Organic fertilizers

Manures, waste hay, straw and other organic materials all contain nitrogen and other elements in variable amounts. These substances become available as the organic matter breaks down. On the whole, fertilization with organic materials is more expensive and less satisfactory than with inorganic (chemical) fertilizers. Organic matter is valuable principally for the beneficial effect it has on soil structure.

Organisms causing decomposition of organic matter in the soil require nitrogen for their activities. When organic matter is abundant, temperature low and the nitrogen supply limited, decay proceeds slowly. The available nitrogen goes into the bodies of the organisms and remains unavailable to plants until most of the organic matter and the bacteria and molds break down. With warmth and a plentiful supply of nitrogen, the decay process speeds up and excess nitrogen becomes available to the plants.

If you use organic matter principally for the plant nutrients it contains, have it analyzed and compute your costs per pound as compared with the cost of a good chemical fertilizer. Remember, it costs more to spread manure and you may introduce troublesome weeds. Also, a large percentage of the nitrogen may be lost to the atmosphere if the manure is not quickly incorporated into the soil. Another factor to consider is its decomposition process. Organic matter breaks down and may release more nitrogen in the summer than is needed for orange trees. High nitrogen in the summer is not conducive to good orange fruit quality.

Soil amendments

A soil amendment is a material that is added to the soil primarily to improve its physical characteristics. (Good soil conditions help roots function properly. Water, air and mineral nutrients become more available.)

Sulfur. This is sometimes used in citrus groves to make the soil more acid or to improve water penetration, but there have been occasions when unfavorable effects on soil structure developed from soil sulfur applications. Sulfur is useful in certain types of alkali reclamation but is not generally recommended for use in citrus groves.

Gypsum. This is used to furnish calcium for soils low in this element. It is usually necessary to add gypsum to irrigation water carrying a high percentage of sodium even though the water may be quite low in total salts. Gypsum also helps correct unfavorable structural changes in the soil caused by repeated use of ammonium fertilizers.

Iron sulfate (ferric or ferrous sulfate). These iron compounds act similarly to gypsum, and where calcium is already abundant in the soil their use sometimes helps overcome lime-induced chlorosis.

Iron-sulfate compounds must not cover leaves and fruit or they will pit and burn them.

Lime (calcium carbonate) is an alkaline compound which may increase soil alkalinity. It is used to correct acid soils. Such soils are occasionally found in California citrus areas. Nevertheless, lime is not needed for these soils.

Organic matter. This includes manure, cover crops, wood waste, and sewage sludge. Incorporated into the soil, organic matter helps maintain good structure and prevents loss of fertilizing elements. Excessive use of manure may aggravate certain mineral deficiencies and may cause boron or salt excesses.

Cover crops and green manure

Where tillage is practiced, winter cover crops help overcome the deleterious effects of cultivation. These crops also help prevent soil erosion, break up compaction layers (plow sole) and generally improve the physical condition of the soil. The chief disadvantages of a winter cover crop are the lower temperatures it causes and its interference with orchard traffic, particularly with winter harvesting and heating operations.

Cover crops most commonly used are the legumes, purple vetch, and *Melilotus indica*—the mustards and mallow. Volunteer annual weed cover may serve as well. A mixture of barley and vetch is often preferred. It is sown at the rate of 10 pounds of each per acre. Late September or early October is usually the best time to plant the cover crop. Drill it in or broadcast and harrow just before furrowing out for irrigation. If purple vetch is seeded alone, use 25 to 30 pounds per acre.

Small seeds such as melilotus and mustard do best if broadcast after furrowing out and just before irrigation. *Melilotus indica* is seeded 10 to 15 pounds per acre. White mustard (*Brassica alba*) does best on lighter soils but is easily damaged by grove traffic. It is seeded 8 to 10 pounds per acre. Black or brown (trieste) mustard (*Brassica nigra*) is seeded 6 to 8 pounds per acre and usually recovers from trampling incidental to orchard operations. When natural growth is used as a cover crop, it is necessary only to omit fall tillage and allow the weeds to grow.

Turn the winter cover crop under as soon as possible after the middle of February. If the cover crop produces too much growth, or if it starts to mature before the soil is in condition for discing, mow it or break it down with a drag to retard its development until you can work it.

As indicated in the discussion on organic fertilizers, large amounts of undecomposed organic matter may seriously reduce the availability of nitrogen. For this reason avoid excessive cover crop growth and do not permit any cover crop to mature and become woody. Cover crops are beneficial only when properly managed.

Summer cover crops are not generally recommended because they compete with the trees for both water and fertility. This is particularly true where bermudagrass becomes established. A limited amount of annual weed growth, however, will not be detrimental and may assist in erosion control. If you attempt to completely suppress all growth by cultivation you till the soil excessively and cause detrimental structural changes to occur.

Permanent cover crops have been used from time to time for many years. In almost all instances the trees do not grow or fruit as well as when weed growth is suppressed. Rodent damage usually increases and the cover crop out-competes the trees for water and nutrients.

Permanent strip cover crops have been

Permanent strip cover crop. Note absence of sod growth in tree row where weeds are controlled with herbicides.

used to advantage in controlling erosion and improving water penetration in orchards under sprinkler irrigation planted on slopes or hilly land. In this practice, a strip of annual grasses 6 to 8 feet wide is maintained in the drive between each row. Weeds in the tree row are controlled by herbicides, and growth of the grass strip is controlled by mowing. Care must be taken to prevent perennial grasses such as bermudagrass and Johnsongrass to become established. With any permanent cover, additional nutrients and water will be necessary to prevent excessive competition with the trees.

Intercropping young orchards succeeds only where the intercrop is compatible with the water and nutrient requirements of the young trees and where competition is avoided. Many growers who tried intercropping regretted having planted the intercrop because they found that they were unable to properly care for the newly planted orchard.

Why cultivate?

The most important reasons for cultivating citrus orchard soils are to control weeds which compete with trees for fertility and moisture, to prepare for irrigation and harvesting, and to incorporate cover crops and bulky organic materials into the soil.

Cultivation destroys surface citrus roots. You also lose the function of a portion of the best aerated and most fertile soil, often at times when it is most needed. On shallow soils this can be serious. Cultivation affects soil structure unfavorably, compacts soil, and causes water to penetrate less readily. The obvious conclusion is—the less cultivation, the better.

A common practice is to disc the soil as soon as possible after the winter rains, usually in the latter part of February or early March. Subsequent cultivation is done with a disc or a spring-tooth harrow after every second or third irrigation and until the winter cover crop is sown.

Applying herbicides for weed control in nontilled orchard.

Non-tillage. Because of the disadvantages of tillage and the advantages of non-tillage, the majority of California citrus orchardists now control weed growth with weed oil and soil sterilants. Costs may be greater the first year or two, but after that it is cheaper to control weeds by means of herbicidal sprays. With the soil bare and firm, more heat is absorbed and radiated, warming the orchard on cold nights. Fruit quality improves because there is less mechanical injury. Sometimes better yields are obtained. On some soils remarkable improvement in water penetration takes place and larger fruit results. With no cover crop the drive-rows may be sanded and picking carried on soon after rains.

To set up furrow irrigation and non-tillage, construct three broad-based furrows so that orchard equipment rides on the two middle ridges. A uniform slope with a return-flow system helps prevent difficulties in water handling. Apply soil sterilants when the soil is bare and herbicides when the weeds are only an inch or two high. Check with your Farm Advisor or Agricultural Commissioner for permissible soil sterilants and herbicides to use. (See *Chemical Weed Control in Citrus*, University of California Division of Agricultural Science leaflet 191.)

Apply soil sterilants in late fall or early spring so the rains will activate them. Temporary soil sterilants kill germinating weed seedlings and do not harm the trees if the label recommendations are carefully followed. (There is no basis for the

Return-flow installation showing sump, small electric sump-pump, and standpipe to provide head for return flow.

belief by some that chemical weed control harms the soil.)

Frost protection

All California citrus districts are subject to occasional frost damage, and about every 10 to 14 years there is a freeze severe enough to require considerable effort to prevent serious losses to trees and crop. Local radiational frosts occur almost every year. Your particular location may or may not be subject to extensive cold damage. Your decision as to whether you should provide frost protection depends on how much you save by your investment in frost protection equipment, labor and management.

Orchard heaters, wind machines and running water down the furrow or in basins are conventional means of frost protection. Other devices have been tried but few show promise of becoming a part of the frost protection program.

Heaters. Most citrus districts are subject to air pollution control and growers must use only certain specified heaters. Consult your Agricultural Commissioner for local regulations.

If you depend solely on orchard heaters you need 50 to 70 standard nine-gallon oil burners per acre. Oil storage to insure adequate supply in an emergency should be provided. Fill all heaters and have about 1,000 gallons per acre on hand by November 1 of each winter season.

Place your heaters so that you obtain the most uniform distribution of radiant heat possible. If there is one heater for two trees, place them in the center of the space between each set of four trees. The heaters in one row should be staggered with those in the next. Place heaters to facilitate filling and to provide maximum effectiveness. Light only a portion of the heaters first, such as every fourth row or every other row as needed. As temperatures drop, light more heaters. Provide two heaters per tree on outside borders in districts subject to cold air drift into the grove. One heater per tree in the first two rows inside the border also helps. Operate all border heaters at the normal burning rate. Keep the burning rates of the heaters in the central areas of the orchards as low as possible to reduce the amount of cold air drawn in by the updraft.

Wind machines. Wind machines alone may protect citrus down to 22° F. provided there is sufficient temperature inversion and they have enough horsepower per acre (develop enough "thrust") to do the job. Usually 5 to 8 bhp (brake horsepower at the propeller) per acre is required. A small machine (15 bhp) will be unable to utilize temperature inversion sufficiently to do much good. Several small machines could be helpful, but are not usually as effective as a single large machine. The more machines operating in a district, the more effective the frost protection afforded by each machine.

If fruit and foliage are cooler than the air, wind machines help, especially when trees are small. With no inversion layer and no other source of heat such as heaters and running water, and with the air colder than the trees and fruit, wind machine operation would be harmful—but such occasions are rare.

For more details on wind machine operation and frost protection in general, the grower (or potential grower) is advised to see *Frost Protection in Citrus*, University of California Agricultural Extension Service Publication AXT-108.

The combination of wind machines *and* 15 to 20 properly spaced heaters per acre warms the grove more than wind machines or heaters used alone.

Water. Running water in an orchard on a cold night adds heat to the orchard; the higher the water temperature, the more heat released. When water freezes it gives up a large amount of heat; but similarly

when ice thaws, it takes up heat. Thus this method is most effective if the surplus water is removed from the grove. If ice does form, run water over it until it melts. Underhead sprinklers can be used, but there must be enough of them to cover the ground. Overhead sprinklers may load the trees with ice and severe breakage and fruit damage result. Furthermore, unless ample water is provided, the plant may be cooled by evaporation to several degrees below air temperatures. Water for frost protection is inadvisable for orchards on clay soils. Damage may occur from waterlogging and fungus infection if cold periods are of long duration.

Combinations of two or all three of the above heating methods may be used if provisions for refueling and for surplus water removal are made.

Windbreaks. Suitable windbreaks greatly reduce damage to trees and fruit in areas subject to occasional high winds, to strong prevailing winds, or to chilling winds.

Winds from 15 to 20 miles per hour cause some fruit scarring; at 25 to 30 miles per hour some fruit is shaken off; at 30 to 40 miles per hour most fruit falls to the ground in unprotected areas. As the velocity increases more and more leaves blow off. Packing house records show large increases in yields and fruit quality from windbreak-protected orchards as compared with adjacent blocks of unprotected trees. Tree growth may be much retarded in groves without windbreak protection.

The usefulness of windbreaks has been demonstrated repeatedly, but they do cause problems. Windbreak trees compete with orchard trees for water and nutrients. They shade adjacent citrus, slow the movement of cold air out of the orchard causing cold pockets, and they inconvenience orchard operations. In areas subject to infrequent losses from occasional winds, the advantages of having a windbreak must be weighed against the disadvantages.

Windbreaks have a cumulative effect; the more wind protection in an area, the greater the effectiveness of any given row of windbreak trees. While the removal of windbreak trees in a row or two of the orchard may not greatly reduce the usefulness of remaining windbreak trees, the total lack of windbreaks in an area causes considerable difference in air velocity.

A windbreak provides lateral protection at orchard tree level for about 4 to 6 times its height. In unplanted areas, anticipate the height your windbreak trees will grow and plant them as near as possible at right angles to damaging winds. If time permits, establish the windbreak before planting the new orchard. Allow plenty of room next to the windbreak for orchard operations.

Ideally, the dominant windbreak tree should be narrow, tall, mechanically strong, rapid growing, dense and free from insects and diseases. Best variety for each district varies according to the soil, available water, climate and general adaptability.

Trees most commonly used for windbreak include several eucalyptus species, cypress and tamarisk. Consult your Farm Advisor for the best for your area.

Where windbreak protection cannot be provided for newly-planted trees, individual shelters placed on the windward side of the trees protects them until the planted windbreak grows big enough to do the job. Such shelters may be of lath, burlap, palm fronds, or similar materials.

For rapid growth give the windbreak trees adequate water and fertilizer. Bluegum windbreaks properly cared for grow 75 feet high or more by the eighth year after planting.

Root competition with citrus can be minimized by regular root pruning to a depth of 3 to 5 feet, and not closer than

12 feet from the windbreak. Cut roots on alternate sides every other year or every 2 years.

Prune windbreak trees to eliminate shading by overhanging branches and to maintain good foliage density. To avoid heavy cutting, prune as necessary. Topping to maintain suitable tree height and to force dense growth may be required. Special tools for root- and top-pruning are used.

Pruning

With all citrus excepting lemons it is axiomatic that "the more you prune, the more you reduce tree growth and production." Yet there is some pruning you must do to maintain desirable tree size and shape, to eliminate an excessive accumulation of dead wood and to remove broken and diseased limbs.

Most lemons require annual and sometimes twice-a-year pruning. This is primarily to facilitate harvesting and to improve fruit size. Oranges and grapefruit, on the other hand, seldom need more than an occasional dead brushing and removal of broken or diseased limbs—until they start to crowd and shade.

Normal citrus trees produce vigorous shoots which may become tangled with older branches. Control this growth by bending and pulling it to the outside. Undesirable vigorous growth is best controlled by suppressing trunk and unwanted limb suckers as they appear. If you wait until they have grown 4 or 5 feet and then prune them out, you stimulate more sucker growth around the cut and lose the leaf surface the large suckers have developed.

When citrus trees suffer from conditions that cause loss of roots, defoliation and dieback of the top follows. If the trees are not killed the tops often remain in an unthrifty condition. Severely dehorning or skeletonizing the main limbs may then improve the root-top relationship, and vigorous new growth may follow. Should the conditions that contribute to unthrifty root growth be corrected top recovery may be expected. If they are not corrected, pruning will not help.

Trees suffering from reduction in leaf surface due to insect infestation, disease, frost, wind or spray injury are best left unpruned until a strong new growth flush develops. The remaining dead brush may then be removed.

With older groves some crowding and shading of lower branches may result in increased harvest costs and decreased yields. Hedging and sometimes topping with mechanical saws may be employed to advantage. A light annual or biennial hand pruning to limit tree size and to prevent shading of the lower limbs before the trees crowd helps avoid drastic pruning. Severe overcrowding may require tree removal rather than excessive pruning. Skeletonized or dehorned trees usually produce larger but fewer fruit. The increase in fruit size does not make up for loss in number of fruit. The net result is that heavily cut back healthy trees suffer considerable production loss.

The best time to prune from the standpoint of the tree is just before growth starts in the spring. This permits the tree full use of its entire leaf surface in winter, and insures rapid replacement of lost foliage by the spring growth flush. Practically, the work is often done at a time that fits into the general management program. To avoid serious losses from cold, however, pruning should not be done in the fall or winter months.

Replanting and intersetting

Eventually all citrus orchards require replacement trees. Gophers, root rot, virus diseases and accidental death take their toll. To maintain high production you need all the tree spaces filled with healthy,

productive trees. Thus, it is essential that all "boarder" trees be removed and replaced with the best young trees available on rootstocks that adapt to old orchard conditions.

Replant and interset trees usually do not thrive as well as trees planted on virgin soil. This results from soil conditions brought about by the presence or remains of citrus roots. Old citrus soil contains substances and organisms toxic to most new citrus roots. This condition persists for several years after citrus trees are removed. As a matter of fact, a depressive effect may be noted on newly-planted sweet seedling roots 20 years after the old trees were removed.

Troyer citrange and trifoliate orange roots are less affected by old orchard soils than are other commercial rootstocks.

Orchard replants and intersets respond favorably to special care in soil preparation, planting, watering, pest and disease control, and fertilization. If possible, remove the old tree several months before replanting or cut back and root prune the orchard prior to intersetting. (This work is preferably done in the summer.) Break up hardpan and other impediments to drainage and root development to a depth of at least 36 inches. The area thus worked should be ample to contain the root system of a full grown tree. Settle the soil by a thorough irrigation. After it is dry enough to work, grade it so you may irrigate properly.

To obtain maximum replant growth, soil fumigation is necessary for all rootstocks. See the *Treatment Guide for California Citrus Crops* for suggested fumigant (see also box on page 47 of this manual), dosage rates and waiting period between fumigation and planting.

Harvesting

The care with which citrus fruit is picked largely determines its length of life and condition in which it reaches the market. Skin punctures, bruises, clipper cuts, and rough handling reduce the packinghouse grades. Rot organisms enter injured rind tissues and decay soon involves many fruit.

Most packinghouses furnish picking crews and it is to the advantage of the management to see that a good job is done. The pickers are usually trained to do the work properly, but it helps to watch for and report picking errors to the fieldman in charge.

In recent years many packinghouses have discarded field boxes and converted to bulk bins. Their use has resulted in better fruit quality by reducing fruit injury through improved field and packinghouse handling. Savings in labor costs have helped pay for conversion to the bulk-bin system. An even more important savings would come from adoption of mechanical harvesting. Because of high picking costs and large seasonal labor requirements, the citrus industry strongly supports engineering research in the attempt to find a suitable means of mass fruit removal. Some progress has been made, but because of variable tree size, fruit size, density of foliage, and care needed in avoiding fruit injury, designing and building machines to do the job properly is extremely difficult. An intensive effort is underway to solve the problem of removing citrus fruit mechanically.

Some recently developed picking aids may prove helpful. "Man-positioning" machines and improved techniques may increase labor output, but it is not yet known whether or not they will significantly reduce harvest costs.

DISEASES AND PESTS

Periodic careful orchard inspection is essential in order to maintain control of diseases and pests. Citrus is subject to a host of disorders and to attacks by many kinds of plant enemies. By frequent observations you may determine when treatment is necessary.

> Because treatments vary considerably as to season and locality, you are referred to the *Treatment Guide for California Citrus Crops* issued by the California Agricultural Experiment Station and Extension Service of the University of California. For a more complete account of citrus diseases, see *Color Handbook of Citrus Diseases* by L. J. Klotz, published by the University of California Division of Agricultural Sciences.

Virus diseases

Psorosis (scaly bark) is a serious virus disease transmitted almost exclusively by infected scion wood and budwood. Root grafting in closely planted orchards also transmits the disease. Concave gum, blind pocket, crinkly leaf, infectious variegation, and Satsuma dwarf are diseases apparently related to psorosis or part of a virus complex that includes psorosis.

As trees of the sweet orange, grapefruit and mandarin mature, the virus causes local areas of the outer bark to die and break away in small irregular shaped scales. Surface bark is killed and new bark forms underneath and continues to scale off. Frequently, pockets of gum develop under the bark, and beads of gum appear in affected areas. As the areas of abnormal bark enlarge, the wood becomes stained, the top starts to die and yields decline. Small, clear streaks or flecks in leaves help experienced persons diagnose psorosis long before bark lesions develop.

Psorosis cannot be cured. If treated in the early stages of the disease, the productive life of the tree may be prolonged. This may be done mechanically by scraping or by painting the affected areas with DN-75 (1 per cent in kerosene). Trees developing bark symptoms early in life (5 to 7 years) and trees showing top deterioration with accompanying low yields (3 boxes or less) should be removed.

Psorosis can be easily prevented by planting only trees propagated from parent trees registered by the nursery service as free from psorosis.

Stubborn (Acorn) disease, like psorosis, occurs wherever citrus is grown in California and is transmitted by budding and grafting. Insect vectors are unknown,

Psorosis-infected tree (tree should have been removed earlier).

Stubborn disease. Tree on right is infected; tree on left is normal.

but there is evidence of some spread in the field. Distorted eccentric or "acorn"-shaped fruit, and sometimes stylar end greening and blue albedo may occur on stubborn trees. In normally seedy fruit, seed abortion occurs. Vegetative symptoms are stiff, upright multiple twigs and buds, with smaller appressed, cupped upright leaves that may be mottled or chlorotic. Trunk bark may be thickened near the bud union, and trees are usually stunted. Considerable off-bloom may occur. Yields are depressed. The whole tree may be affected or only a limb may show symptoms of the disorder. Stubborn has many similarities to the South African greening disease which is spread by the citrus psylla, an insect not present in California. Nursery trees affected with stubborn disease grow less vigorously and produce many more and smaller leaves along the growing shoots due to the short internodes and impaired nutrition.

Careful bud selection from stubborn-free trees is the only known control. Remove all poor producing trees showing symptoms of this disease.

Tristeza (quick decline) is nearly world-wide in distribution. Decline and sudden collapse of sweet orange on sour orange and some other rootstocks are the most noticeable symptoms. Sweet orange, mandarins and other scion varieties may be stunted and suffer reduced yields on infected grapefruit and some other rootstocks. Collapse is caused by death of the tissues that conduct nutrients to the roots; the roots starve and are unable to pick up needed moisture and minerals for the top. During warm or dry weather sudden wilting and death of the top may occur. Frequently, affected trees make some recovery but eventually production declines sufficiently to require removal. Honey-combing (fine pitting) of the bark of susceptible rootstocks near the bud

unions is another symptom associated with tristeza. Early stages of the disease may cause thinning and bronzing of the foliage and the setting of heavy crops of small fruit.

Tristeza is spread by the cotton or melon aphid and by infected propagation wood. Control requires use of resistant rootstocks of trifoliate orange, sweet orange, rough lemon, Troyer citrange and Cleopatra mandarin. *Citrus macrophylla* (a rootstock for lemons) is highly susceptable to tristeza, but when the lemon scion is established infection is unlikely. Therefore it is important to grow lemon nursery stock in locations free from tristeza infection. In areas of limited infection, strict quarantine, eradication of all infected host plants, vector control and especially the use of virus-free budwood helps prevent spread.

Exocortis (scaly butt, Rangpur lime disease) causes cracking, discoloration, scaling and stunting in susceptible citrus varieties. Trifoliate orange, citranges, Rangpur lime and other mandarin limes, sweet limes, some lemons and citrons are attacked. As with tristeza, resistant rootstocks budded to resistant scion varieties may become infected and act as symptomless carriers of the exocortis virus. Use of exocortis-free budwood on susceptible rootstock is the only known means of control. Exocortis-affected young trees often yield well for a few years but then production drops and the stunted trees fail to produce satisfactory crops. There is evidence that exocortis can be transmitted by budding and pruning tools but its spread in orchards has been slow.

Cachexia-Xyloporosis reduces vigor and yields and may eventually kill infected trees. Lens-shaped pits are found in the trunk wood, with or without gumming; pegs on the inner bark surface and gum deposits in the bark may also be seen. There is no known vector. Budding and grafting (and possibly infected seed) spreads the disorder. Sweet limes, mandarins, mandarin limes, tangelos and *C. macrophylla* are attacked. To prevent this disorder, use seed and budwood from disease-free sources or avoid susceptible scions and rootstocks.

Vein enation (Woody gall) causes small projections (enations) on the undersurface of veins and corresponding concavities on the upper surface. Woody galls may appear on the trunk of rough lemon and lemon branches and roots. Affected trees grow and produce poorly. Aphid species that spread the disorder in California are *Aphis gossypii* and *Myzus persicae*. Budding and grafting is the other known means of transmission. Sweet and sour oranges, Mexican lime, lemon and rough lemon are the principal varieties attacked. Enations are rather rare on infected mature trees, but appear in nursery trees. Control consists of avoiding the use of rough lemon rootstock. The use of virus-free budwood is recommended in areas where vein enation virus is rare.

Several other virus diseases attack citrus, but are yet of slight economic significance in California.

Fungus diseases

Brown rot gummosis, also called foot-rot, occurs on the citrus varieties grown in California. The principal fungi causing the trouble are *Phytophthora citrophthora* and *P. parasitica*. *P. citrophthora* works in cool weather and *P. parasitica* is most active in the summer. They attack and kill the bark at or near the ground level. Large quantities of gum are usually produced when the infection is above ground. For this reason the disease is commonly referred to as gummosis.

Lime and lemon varieties are most susceptible to the brown-rot fungi; orange, grapefruit and mandarin varieties are somewhat resistant. Of the common rootstocks, trifoliate orange is most resistant;

Troyer citrange, Cleopatra mandarin and sour orange show considerable resistance. (Cleopatra mandarin is quite susceptible to *P. parasitica.*) Sweet orange, rough lemon and grapefruit often become infected when conditions favor the fungus, such as wet soil remaining in contact with the bark of the crown roots and trunk.

To avoid gummosis, plant your trees high enough so that after settling the point at which the first lateral roots branch out is at the ground level. On heavy soil it is especially important to use resistant rootstocks. Where footrot is a problem, remove all soil around the trunk down to, or even below, the first lateral roots; keep this area free of trash and as dry as possible. Avoid water application around the trunk of the tree, and *avoid wetting the trunk with sprinklers.*

See the *Treatment Guide for California Citrus Crops* and U.C. Circular 396 entitled *Gum Diseases of Citrus in California* for suggested treatments.

Where the bark has been killed more than half-way around remove the tree and replant, preferably with resistant rootstocks following appropriate fumigation.

Phytophthora hibernalis and *P. syringae* in wet years often cause severe defoliation and twig dieback. Bordeaux sprays help prevent this trouble.

Phytophora parasitica may kill enough feeder roots to cause sudden collapse and death of the top. Wet soils contribute to infection. A number of other fungi such as *Diplodia, Botrytis, Dothiorella, Sclerotinia, Fusarium, Thialaviopsis, Rhizopus,* and *Macrophomina* also cause root rot or act as secondary infectious agents. Providing good drainage and careful irrigation helps prevent trouble from these fungi.

Brown rot of fruit, an important type of fruit decay, is also caused by species of *Phytophthora.* Spores of the fungus splash by rain onto fruit near the ground producing a light-brown colored decay that rapidly involves the whole fruit, which despite this stays firm for a number of days or weeks.

Rain and long periods of damp weather favor brown rot. Lemons are most seriously affected but all citrus varieties are susceptible. Preventive spraying with Bordeaux mixture before the rainy season starts helps control infections. Weeds and soil near the skirts of the trees as well as the foliage at least 3 to 4 feet off the ground should be well covered. (Consult your local agricultural authorities for the copper formulation to use. In some areas copper-bearing sprays cause severe burning of fruit and foliage.)

Septoria spot caused by species of Septoria may seriously reduce the grade of grapefruit, Valencia oranges and lemons. It causes pitting and "tear" staining of the rind on unprotected fruit—especially in wet weather. Bordeaux sprays over the entire tree (as suggested in the *Treatment Guide for California Citrus Crops*) control these fungi.

Oak root fungus parasitizes citrus roots in limited areas in California. The causal organism, *Armillaria mellea,* is often present where oak and other native trees have been removed or where flood waters have deposited infected wood. It causes a moist decay of bark and wood and can be identified by the white, fan-shaped fungus growth which develops in and under the bark, or by dark, root-like strands growing on the surface of roots. During late fall or early winter groups of light brown toadstools may be produced.

All citrus rootstocks are susceptible, and trifoliate and Troyer citrange seem particularly sensitive. The disease may be retarded by exposing the crown roots and trunk so they remain dry. No cure is known. The fungus in the soil must be destroyed by fumigation with carbon disulfide before replanting.

Shell bark (decorticosis) is a malady common to all lemon-growing areas of

California. The outer bark of affected lemon trunks dies and breaks away in large vertical strips as new bark forms underneath. During the more active stages of the disease, the foliage becomes thin and off-color with considerable twig dieback. All or part of the top may be affected. Scaling of the bark usually starts near the bud union or just below the main branches and gradually involves the whole trunk; it may even progress into the main branches of old trees. Many different fungi have been found associated with shell bark and these fungi often cause some gumming. Exocortis virus may be a factor in shell bark development. Susceptibility to shell bark is inherited; some lemon trees, including many Lisbons are more resistant than Eurekas to shell bark.

Dry bark is similar to shell bark, but the fungus infections are very severe. Dry bark causes serious losses in some coastal orchards. Areas of dead, dry bark appear on the trunk and main limbs and enlarge until the tree becomes unproductive. Affected trees may decline severely in a few months but may continue to produce some fruit for several years. Severe top-pruning may stimulate regeneration of bark and some recovery. In some areas periodic and fairly severe pruning is advisable to delay dry bark and reduce its severity. Some Lisbon lemons are resistant to dry bark, but may not be horticulturally suitable in some areas.

The best control measure for both shell bark and dry bark is to use virus-free budlines from healthy 20-year-old or older trees growing in an area where these diseases occur in abundance. High budding and regular pruning help reduce the severity of these disorders.

Lemon sieve-tube necrosis is an important disorder of some lemon clones. The necrosis, or death, of the sieve tubes in the trunk limits the transfer of food materials and metabolism products and causes a decline or collapse of the tree. The exact cause of sieve-tube necrosis is not established. It may be an inherited weakness or possibly a virus disease. It occurs in some clones and not in others. In any given clone subject to the disease, the effects are more severe in coastal areas than in inland areas.

Control is through the use of lemon clones which are free from this disorder and which are adapted to the area in which the orchard is planted. Your County Farm Advisor can advise you as to the best selection for your area.

Dry root rot occurs in all commercial rootstocks when conditions favor the growth of the organisms causing this disorder. The fungi *Fusarium* sp., *Macrophomina* sp. and *Chaetomium* sp. and certain kinds of bacteria are associated with this trouble. Sudden wilting as in the collapse stage of tristeza, occurs when most of the root system is involved. The roots show moist decay that later dries, cracks, and shreds. A dusky to black discoloration of the wood may be revealed by cutting through the roots. Deteriorated roots become punky in texture.

Damage to roots by excess fertilization, irrigation, herbicides and nematocides or rodent activity and tillage injury provides entrance for agents causing dry root rot. To prevent trouble from this disease avoid all types of root injury.

Bacterial diseases

Citrus blast and *black pit* are caused by the bacterium, *Pseudomonas syringae*. Oranges and grapefruit are most susceptible to injury in the leaves and twigs, while fruit spotting occurs on lemon fruit. Blast is usually active in winter and spring and in wet, windy years. It is a serious disorder of orange trees in northern California with only occasional appearances in other areas of the state. With oranges, blast lesions often start at the wing of the petiole and extend rapidly to

the leaf base. Callus forms and the affected part becomes a scabby, reddish-brown. Leaves often wither and dry while attached, or fall off. Twigs may be girdled and die back. Black pit of lemons occurs in cool, moist weather following injury by hail, punctures, and abrasions.

Blast injury is lessened by cultural methods to prevent late fall growth, by use of wind breaks and compact-growing varieties free of thorns, by removal of infected wood in the spring after the rains stop, and by spraying with Bordeaux in November.

Physiological and complex disorders

Wind burn causes fruit injury and loss of leaves by dehydration and mechanical abrasion. Windbreaks help prevent this damage.

Leaf scorch is noted as a progressive bronzing and pitting, and curling of leaves, mostly in the south and west portion of the exposed foliage. Excessive reflected heat in hot, dry areas contribute largely to this disorder. Proper irrigation and good nutrition to help keep the trees in a thrifty growing condition minimizes leaf scorch.

Twig dieback and leaf drop occur periodically on orange trees in most districts of the state. There are several contributing causes to these maladies. Most important are the sudden, relatively hot spring temperatures which greatly increase transpiration from the tree while the roots are still inactive in cold soil. During such periods the tree is under a stress for water even though there may be ample moisture in the soil. This stress often causes gum to form in the conductive tissues of the twigs further restricting water movement. Drying of the leaves and death of the twigs may be immediate or may occur a few weeks later, often at the time of a subsequent hot period.

Other factors which cause water stress and contribute to twig dieback and defoliation are dry soils, excess salts, fibrous root system damage by fungus and red spider mite infestations. Keeping trees healthy, free from pests and supplied with adequate moisture will minimize the occurrence of twig dieback and defoliation. Severe overgrowth at the bud unions on many commercial rootstocks are responsible for some losses in lemon-growing districts, although the causes are unknown. Trees in coastal areas appear to be the most affected by this disorder.

Pests

Pest control is one of the most expensive, difficult and critical operations in citrus production because local and seasonal cli-

Twig dieback and leaf drop on orange tree.

matic differences must be taken into account in all control work. For this reason, general recommendations have little value. Before doing control work, consult the University of California Farm Advisor, your County Agricultural Inspector, or a competent entomologist. Keep a copy of the *Treatment Guide for California Citrus Crops* on hand for reference. The following is a brief description of the more important pests, together with a statement on their distribution.

Insects and mites

California red scale, *Aonidiella aurantii* (Mask.), is present in most citrus growing areas of California. It is found on the leaves, twigs and fruit and produces a toxic substance which frequently kills leaves and twigs and large branches. The scale is reddish-brown, almost round, and a little over $\frac{1}{12}$ inch in diameter. On green fruit and leaves it causes a yellow spot somewhat larger than the scale; on leaves the spot extends through to the opposite side. Control measures should be taken before red scale becomes abundant.

Yellow scale, *Aoniedella citrina* (Coq.), is found in several citrus districts but damage is generally restricted to the southern San Joaquin Valley and may be mixed with red scale. It is more abundant in this area than red scale. Yellow scale is about the same size and shape as red scale and colonizes principally on leaves and fruit, although present on twigs to a limited extent.

Only by careful examination may you distinguish between yellow and red scale. Yellow scale produces a more markedly yellow spot on leaves and fruit. It may cause heavy leaf drop but does not cause serious dieback unless the population is exceedingly high. It seldom occurs on the wood.

Purple scale, *Lepidosaphes beckii* (Newm.), is a serious pest in coastal areas. It attacks leaves, twigs and fruit. This scale, like red scale, produces a toxic substance which kills the more heavily-infected parts of the tree. It is dark purplish in color; both male and female are oyster-shaped. The female is about $\frac{1}{8}$ of an inch long and the male much shorter and narrower.

Citricola scale, *Coccus pseudomagnoliarum* (Kuw.), is found in most interior districts. The adult female is gray, oblong and about $\frac{3}{16}$ of an inch long. It excretes copious amounts of honeydew on leaves and fruit which becomes blackened with the sooty mold fungus. This insect is single brooded and the population is fairly uniform in development.

Brown soft scale, *Coccus hesperidium* (L.), is often found in association with citricola scale. The adult female is brown, oval, and about the same size as citricola scale. As with citricola scale, no males have been found in California. There are 3 to 5 generations a year and all stages of the insect may be seen in the same colony at one time. Like citricola scale, the feeding of the brown soft scale produces large amounts of honeydew which in turn becomes infested with sooty mold fungus.

Black scale, *Saissetia oleae* (Bern.), is widely distributed in coastal and intermediate areas. Females are dark brown to black, hemispherical, about $\frac{1}{8}$ to $\frac{3}{16}$ inch in diameter and usually have ridges on the back which form the letter "H." This insect also produces copious amounts of honeydew and sooty mold which reduces leaf function and is difficult and expensive to remove from fruit.

Cottony-cushion scale, *Icerya purchasi* (Mask.), is found mostly in central California. Mature females or hermaphrodites have reddish-brown bodies and black legs and antennae; the most conspiciuous characteristic is the large, enlongated, fluted egg sac which becomes up to $2\frac{1}{2}$ times as long as the body of the adult female (which measures to $\frac{5}{8}$ inch long).

Inside the egg sacs may be found 600 to 1,000 bright red oblong eggs. Feeding of the insect causes defoliation, fruit-drop and honeydew excretion which becomes covered with sooty mold fungi.

Citrus thrips, *Scirtothrips citri* (Moult.), is a major pest in the interior and intermediate areas of California. It is a small, active light-yellow insect, about $\frac{1}{30}$ inch long, which rasps the fruit and leaves in the very young stages. Scarred and distorted leaves result, as well as multiple buds and fruit which has an irregular circular scar around the stem end and irregular scars on other areas.

Thrips feed on tender foliage throughout the growing season. Injury to fruit begins at petal fall time, immediately following blossoming and until the fruit becomes about golf ball size.

Citrus red mite, *Panonychus citri* (McGregor), commonly known as red spider, is probably the most serious pest attacking citrus. It feeds on leaves and fruit which becomes silvery gray and dry appearing. Many of the leaves fall prematurely. The mite is deep purplish red and difficult to see because of its small size. It is found in most of the citrus producing areas of California. Hot weather kills a large percentage of the population and cold weather inactivates the pest. It thrives during mild, humid weather.

Citrus bud mite, *Eriophyes sheldoni* (Ewing), is a pest in coastal and adjacent areas of southern California. It is more serious on lemons than oranges. Adults are so small they are hard to see with a 12-power hand lens, but their presence is characterized by distorted leaves and fruit which result from their feeding.

Citrus flat mite, *Brevipalpus lewisi* (McGregor), causes spotting and scabbing of orange fruit in the San Joaquin and Sacramento Valleys and can be found on grapefruit and lemons in Coachella Valley.

Other mites occasionally attacking citrus and causing considerable damage are Yuma mite, *Eotetranychus yumensis* (McGregor); Lewis mite, *Eotetranychus lewisi* (McGregor); two-spotted mite, *Tetranychus telarius* (L.); Pacific mite, *Tetranychus pacificus* (McGregor); six-spotted mite, *Eotetranychus sexmaculatus* (Riley); and the Rust mite, *Phyllocoptruta oleivora* (Ashmead).

Aphids of several species attack citrus in all districts, but are most important in coastal and intermediate areas. They are not a serious pest of lemons but often feed in large numbers on the tender growth and blossoms of oranges and grapefruit. They sometimes cause "bumpy" fruit. Growth distortion and stunting results from feeding on new shoots. Aphids have many enemies and are often destroyed by unfavorable weather, but have such ability to multiply that they may do extensive damage in a short time.

Mealy bugs occur principally in coastal areas. Although biological control usually holds these pests in check, occasionally they cause injury by their feeding and the excretion of large amounts of honeydew.

Orange worms of several species may cause severe growth reduction and fruit injury. Damage tends to occur in localized areas and is sporadic.

Katydids and grasshoppers, like the various kinds of orange worms, tend to localize their attacks. Katydids damage newly formed oranges by chewing a portion of the developing fruit which leaves a large unsightly scar on the rind of the mature orange. Grasshoppers migrate from uncultivated areas to attack bordering citrus orchards. They may completely defoliate trees.

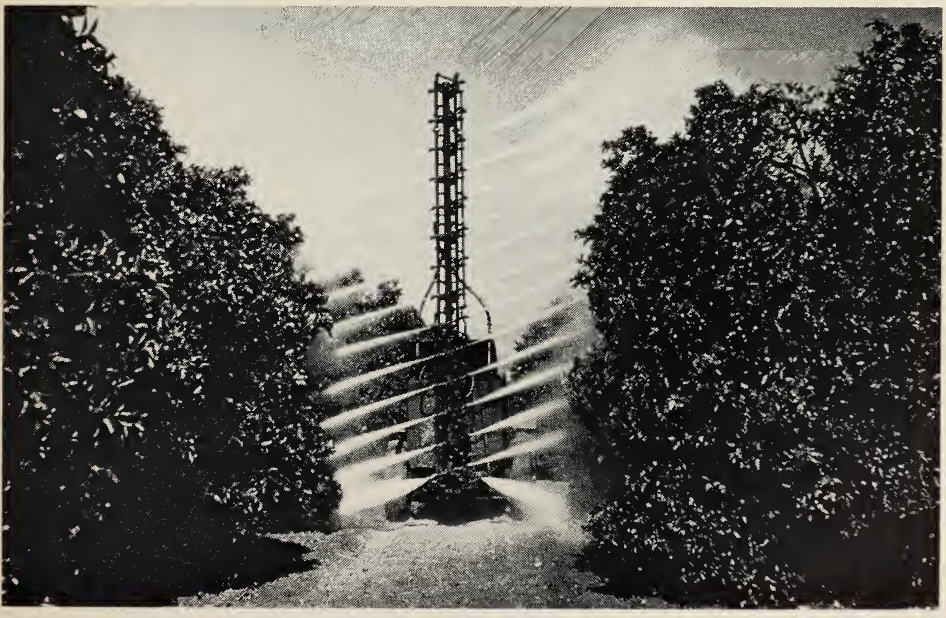
Ants interfere with biological control by protecting insects that excrete honeydew. The fire ant, *Solenopsis geminata* (Fab.), causes injury by feeding on tender twigs, bark and leaves of citrus trees. Ants will sometimes damage or kill young trees by girdling them.

Other insects causing economic damage to citrus are greenhouse thrips, potato leaf hopper, Fuller rose beetle, white fly, earwigs, darkling ground beetle, western spotted cucumber beetle, and false cinch bug. When these or other insects appear in damaging numbers, apply suitable control measures as soon as possible.

CHEMICAL VS. BIOLOGICAL CONTROL

Sooner or later destructive insect and mite populations become controlled by natural enemies, disease, or environmental adversities. For the cheapest, most effective job of pest control you utilize all these factors —plus chemicals when conditions require their use. You cannot allow insects and mites to render your fruit unmarketable or stunt your young trees' growth. You must destroy these pests before your trees suffer serious foliage losses and fruit scarring. Your decision as when to apply chemicals and when to let natural enemies do the job is a matter requiring good judgment and expert knowledge of insect and mite control factors. An *integrated* pest control program is best, using chemicals as needed but avoiding destruction of beneficial insects and mites whenever possible; e.g., spray oils are preferred to organic phosphates when protection of cottony-cushion scale, brown soft scale, or citrophilus mealybug insect enemies is indicated. It is seldom possible or desirable to resort entirely to biological control or wholly to chemical control.

Oscillating boom sprayer for pesticide application.



OTHER PESTS

Snails may cause serious damage to coastal citrus. They feed on leaves and bark and eat holes in the rind of fruit. Slugs confine most of their damage largely to fruits in contact with or close to the ground.

Citrus nematode, *Tylenchulus semipenetrans* (Cobb), is a microscopic roundworm which attacks roots and causes growth reduction, declining yields and reduced fruit size. Badly infested trees may be stunted and show marked deterioration. Heavily infested roots appear "dirty" because of soil particles clinging to gelatinous egg masses. For an account of the citrus nematode and its control see *Citrus Nematode Disease and Its Control*, University of California Agricultural Extension leaflet AXT 211.

Gophers rank among the most important and destructive pests of citrus trees. They frequently girdle the trunk and main roots below the soil level, and the damage is usually unnoticed until the tree begins to lose its leaves and die back. Except in areas where quick decline is quite active, more trees are killed by gophers than by other causes. Be on the lookout for signs of gophers in the orchard and poison, trap, or gas them before the trees are damaged.

Field mice sometimes girdle the trees at or slightly above the soil level, especially in the vicinity of vacant land. They usually avoid trees that have the litter removed two to three feet away from the trunk. When mice damage is evident, control them with poisoned grain scattered in their runs and around the trees.

Deer may destroy outside rows—especially of young trees—in orchards bordering wild areas. On non-bearing trees certain repellent sprays give some protection. Noise makers and depredation hunting permits may have to be used.

Sapsuckers (a species of woodpecker) may girdle older trees grown near wild areas. Painting the trunk and main limbs with a heavy Bordeaux mixture helps discourage their activities. Girdled trees may be saved by inarching or bridge grafting if they are healthy and the damage found soon enough. Special care of inarched seedlings is essential.

CITRICULTURE AS A BUSINESS

You are in the citrus business in order to obtain a reasonable return on your investment. You need, therefore, to measure current and future profit from your orchard operations.

Price, yield and costs are determinants involved in the following "profit" formula.

Net return per acre = on tree price per field box received for all fruit, times yield of fruit per acre, less preharvest production costs per acres.

Since you can do little to influence prices paid for your fruit, your returns are largely determined by your ability to obtain good yields of high-quality fruit, and by how well you keep your production costs at a minimum.

Essential ingredients in business management are adequate capital and labor. Without these you lack the necessary tools to carry on farming operations properly. Maximum yields of high-quality fruit are obtained when you put labor and capital to work at the proper time with the proper equipment.

Getting maximum yields also involves utilizing all your production potential. By

charting your orchard and keeping an orchard inventory you will know where your problem spots are, and you can properly adjust cultural operations to improve production.

To hold costs down you need to know what they are. By keeping accurate, well-organized financial records you provide yourself with the information you need in order to analyze your farm operations and to make pertinent management decisions.

Finally, the grower should affiliate with a reliable packinghouse and marketing organization, and work to support their most efficient operation.

RECOMMENDED READING

For additional information you may wish to refer to certain of the publications listed below. Some of the references are out of print but may be available in many libraries throughout the state. The University of California Farm Advisor in your county has current information, particularly with reference to local conditions.

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